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[SEPTEMBER, 1895.]

THE  
SCIENTIFIC TRANSACTIONS  
OF THE  
ROYAL DUBLIN SOCIETY.

VOLUME V. (SERIES II.)

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IX.

SURVEY OF FISHING-GROUNDS, WEST COAST OF IRELAND, 1890-1891.  
REPORT ON THE RARER FISHES. BY ERNEST W. L. HOLT, AND  
W. L. CALDERWOOD, F.R.S.E.

PLATES XXXIX. TO XLIV.

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DUBLIN:  
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.  
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## CORRIGENDA.

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(VOL. V., SERIES II., PT. IX.)

Owing to unavoidable circumstances, one of the Authors whose names appear on the title page of this Paper was unable to give any assistance in the correction of the proofs: consequently, in addition to misprints of comparatively little moment, certain errors of great importance have been allowed to appear, and it is earnestly requested that anyone who may have occasion to consult the Paper will refer to the subjoined list of corrections.

## E R R A T A.

The following are of GREAT IMPORTANCE:—

Page 368, last paragraph,	for	<i>Ireland</i>	read	<i>Iceland</i>
„ 376, 3rd „ „	„	<i>sound</i>	„	<i>second</i>
„ 389, 2nd „ „	„	<i>Ireland</i>	„	<i>Iceland</i>
„ 396, 3rd „ „	„	<i>interhuial</i>	„	<i>interrhinal</i>
„ 404, 6th „ „	„	<i>spots, and more</i>	„	<i>spots, more</i>
„ 423, 3rd line,	„	<i>. The</i>	„	<i>, the</i>
„ 447, 1st line,	„	<i>pelvis.</i>	„	<i>pelvics</i>
„ „ 2nd and 3rd line,	„	<i>snout by</i>	„	<i>snout,</i>
„ 461, 7th line,	„	<i>4·31</i>	„	<i>1·31</i>
„ 472, 2nd „ „	„	<i>oval</i>	„	<i>oral</i>
„ 475, 1st paragraph,	„	<i>by 5</i>	„	<i>by 14</i>
„ 482, 2nd „ „	„	<i>microscopically</i>	„	<i>macroscopically</i>
„ 510, below woodcut,	„	<i>Reduced <math>\times \frac{3}{4}</math></i>	„	<i><math>\times 3</math></i>

Page 455. The second paragraph should read:—

*The species was thus added to the British Fauna, since the Farøe Channel is, strictly speaking, outside the British area.*

# ERRORS OF OMISSION AND TRANSPOSITION.

Page 394. *Raia circularis*, after 3rd paragraph :

The following specimens are of uniform colour, without large ocelli (*R. circularis*, Couch) :—

Off Bolus Head, . . .	115 fathoms, 1 specimen.	Total length, 8 inches.
„ Gregory Sound, . . .	38 „ „ „	„ „ 39 „
„ Achill Head, . . .	154 „ „ „	„ „ 44½ „
„ „ „ . . .	„ „ „	„ „ 22½ „
Downies Bay, . . .	13 „ „ „	„ „ 44 „

The following have conspicuous alar ocelli (*R. miraletus*, Couch) :—

Rosses Bay, 32 to 25 fathoms, 3 specimens. Total length, 24 to 26½ inches.

Page 435, 3rd paragraph :

The subjoined enumeration of specimens taken during the Survey was accidentally omitted from Press. It should be read after “larger specimens” in the 3rd line of the 3rd paragraph :—

In August, great numbers, from less than 1 up to about 2¼ inches, were trawled at 62 to 52 and 80 fathoms, off the Skelligs. In April a specimen of about 4 inches was taken from the stomach of a Witch from 166 fathoms, 20 miles off Black Rock. In July, a few, from 4½ to 5 inches, occurred at 220 fathoms, and a great number at 144 fathoms, 40 and 30 miles off Achill Head.

Page. 510. The list of Irish deep-sea fishes is incomplete without mention of two small Scopeloids recorded by Dr. Scharff :—

## *Stomias*, sp.

*R. F. Scharff. Proc. Roy. Ir. Acad, Ser. III., 1., 1891, p. 459.*

Two young examples from 1080 fathoms.

## *Bathytroctes*. (?)

*R. F. Scharff. Loc. cit.*

One specimen from 1080 fathoms, considered by Dr. Günther as too young for specific or even generic determination.

Page 486 :

*Rhombus Boscii*. The description of this species was intended to precede that of *R. norvegicus* : hence the “preceding” species referred to under *R. Boscii* is *R. megastoma* and not *R. norvegicus*.

[SEPTEMBER, 1895.]

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# SYSTEMATIC LIST OF SPECIES,\*

SEPARATED INTO "LITTORAL" AND "DEEP-SEA" GROUPS, BY CAPTURE ABOVE OR BELOW THE 100 FATHOM LINE; GREATEST DEPTH, IN THIS INSTANCE, BEING 500 FATHOMS.

## LITTORAL.

### ELASMOBRANCHII :

*Raia maculata.*  
*Raia blanda.*  
*Raia microcellata.*

### TELEOSTEI :

*Gobius Friesii.*  
*Aphia pellucida.*

### TELEOSTEI :

*Crystallogobius Nilssonii.*  
*Callionymus maculatus.*  
*Gadus merlangus.*  
*Rhombus norvegicus.*  
*Arnoglossus laterna.*  
*Arnoglossus Grohmanni.*

## DEEP-SEA.

### ELASMOBRANCHII .

*Chimæra monstrosa.*  
*Galeus vulgaris.*  
*Scyllium canicula.*  
*Pristiurus melanostoma.*  
*Acanthias vulgaris.*  
*Centrophorus squamosus.*  
*Raia batis.*  
*Raia oxyrhynchus.*  
*Raia fullonica.*  
*Raia circularis.*

### TELEOSTEI :

*Pomatomus telescopium.*  
*Scorpena dactyloptera.*  
*Hoplostethus mediterraneum.*  
*Lepidopus caudatus.*  
*Trichiurus lepturus.*  
*Echeneis remora.*  
*Capros aper.*  
*Schedophilus medusophagus.*  
*Cottus quadricornis.*  
*Trigla cuculus.*  
*Trigla lyra.*  
*Lophius piscatorius.*  
*Liparis vulgaris.*  
*Carelophus Ascanii.*  
*Trachypterus arcticus.*  
*Gobius Jeffreysii.*  
*Callionymus lyra.*

### TELEOSTEI :

*Gadus morrhua.*  
*Gadus aeglefinus.*  
*Gadus poutassou.*  
*Gadus Esmarkii.*  
*Gadus argenteus.*  
*Mora mediterranea.*  
*Merluccius vulgaris.*  
*Phycis Aldrichii.*  
*Phycis blennioides.*  
*Haloporphyrus eques.*  
*Molva vulgaris.*  
*Motella cimbria.*  
*Motella tricirrata.*  
*Brosmius brosme.*  
*Macrurus caelorhynchus.*  
*Macrurus rupestris.*  
*Macrurus æqualis.*  
*Macrurus lævis.*  
*Hippoglossus vulgaris.*  
*Hippoglossoides platessoides.*  
*Rhombus megastoma.*  
*Rhombus Boscii.*  
*Pleuronectes cynoglossus.*  
*Solea vulgaris.*  
*Solea Greenii.*  
*Solea variegata.*  
*Argentina sphyraena.*  
*Conger vulgaris.*  
*Nettophichthys retropinnatus.*

\* For Alphabetic List of Species, see p. 512.

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(COMMUNICATED BY THE FISHERY COMMITTEE.)

[ Read DECEMBER 16, 1891.\* ]

## INTRODUCTION.

REPORTS, already published, giving results of fishing operations, have dealt with the commoner forms found during the Survey, and scientific evidence upon economic questions.

A preliminary series of notes has also been published concerning the occurrence of the rarer forms, and, in addition, these have been very briefly dealt with in the reports already alluded to.

In the present Paper we propose to deal with the rarer forms in greater detail, more especially with regard to their structure and affinities, the whole being introduced by some remarks on the vertical and horizontal distribution—a subject which, from the nature of the specimens procured, is of no small interest.

While it is our purpose to treat the shore and deep-sea fishes separately, it is manifestly inconvenient to relegate to distant parts of the text species which, though differing in vertical habitat, are so closely allied as to call for comparative description. We have, therefore, endeavoured to evade the difficulty by affixing to the name of each species the category to which it belongs, whether “deep-sea” or “littoral,” and have further appended a list of the forms which come under these two headings. Purely Pelagic forms are unfortunately not represented in the Survey collections.

In determining the qualifications which relegates a species to one or other category we have followed Dr. Günther,† and shall therefore include amongst the

\* The publication of this Paper has been unavoidably delayed.

† “Report on the Deep-Sea Fishes.”—“Challenger,” vol. xxii.

deep-sea fishes all which have been, or are now for the first time, recorded from depths exceeding one hundred fathoms. That this distinction is to a great extent one of convenience only (since it classes in the abysmal division many forms which have a mainly littoral habitat) has been pointed out by Dr. Günther himself, who has suggested the three-hundred-fathom line as a more natural demarcation. Seeing, however, that the great “Challenger” work is our classic in the literature of the subject, it appears advisable, in a small Paper like the present, to adhere to the limit therein adopted, and thus to avoid a possible source of confusion. We may also remark that since the Macruridæ, a family of typically abysmal structure, sometimes occur in water of less depth than one hundred fathoms, a lowering of the vertical line of demarcation would not be without its disadvantages.

It appears to us that we can greatly enhance the value of this Paper by mentioning in it all deep-sea forms which have been taken off the Irish coast. We only propose however to give descriptions of such as have come under our own observation. In other cases, we shall merely give a reference to the publications in which their occurrence is noted. We shall also refer to the capture, in deep water, in other localities, of species only known as littoral in Irish waters. There is, so far as we are aware, no such list in existence, and it can hardly fail to be convenient to future workers in the same field.

In the case of the purely littoral fishes there is not the same want, since Dr. Scharff’s catalogue of the fishes in the collection of the Science and Art Museum gives a complete list (up to 1889, the date of publication), and we need only note the addition of any species which were obtained since then, either during the Survey or otherwise. It will be understood that species which find a place in the Catalogue, and which are not recorded as abysmal forms in this Paper, are confined, so far as we are aware, to littoral waters.

Since the days when William Andrews and A. G. More explored that district the fish fauna of our most western coast has suffered some neglect. The “Porcupine” made a few hauls of the dredge in the neighbourhood of the bank which now bears its name, and the results formed a few additions to the list of British fishes.\* In 1885 Professor Haddon organised and carried out the first of a series of deep-sea dredging cruises, and since then, up to the commencement of the Survey, no year has elapsed without a record of some good work in this direction.

The valuable contributions to our knowledge of marine invertebrates thus afforded need not be specially referred to, and although the “Lord Bandon” and “Flying Falcon” expeditions yielded information of great interest, the ichthyological results of which have been published by Dr. Scharff,† it was not until

\* Günther, *Ann. Mag. Nat. Hist.*, 1874.

† *Proc. Royal Irish Acad.*, 1890, p. 456.

1889 that the investigation of the abysmal fish-fauna became the subject of chief inquiry. In that year Mr. Green, who had co-operated with Professor Haddon in his earlier cruises, and to whose enthusiasm and practical experience much of the success attending them was due, carried out a series of investigations in the "Flying Fox," which proved of peculiar interest. To certain improvements in the fishing gear, which Mr. Green's practical knowledge of trawling suggested to him, must be attributed, in great part, the unwonted proportion of fish in the hauls of that year. Dr. Günther's paper\* for the first time enabled us to realize how vast a mass of unexplored material lay ready to our hands; and, in the same year, Mr. Bourne's observations, in H.M.S. "Research," Captain Aldrich, R.N., took up the work at the point where Mr. Green had left it, and yielded most valuable results.†

These had led us to expect much from continued work in the same field. To quote Günther's words:—"Not merely in the addition of a number of unknown forms to our list, but equally, and even more, in the certainty that many of the mysteries, which observations limited to the littoral fauna must for ever leave unexplained, will be cleared up by a study of the Pelagic and Bathybial conditions."

The Society's Survey offered peculiar advantages. Whilst its objects—of an economic nature—confined the fishing operations for the most part to the littoral waters, it was none the less incumbent that the deeper regions should also be to some extent explored. Our hopes have not proved without foundation. While extending the horizontal range of several species, by their addition to the British or Irish fauna, we are also able to extend the vertical range of some of them, and it will be seen that this extension may throw light upon the life-history of several forms.

The points in common between the fauna of the West of Ireland and of the Lusitanian region have for many years compelled the attention of naturalists, both in regard to terrestrial organisms and to marine invertebrates. If the similarity of the fish fauna has attracted less notice, it is probably because less attention has been devoted to it, and, perhaps, also because, so far as is known, it is very similar to that of the south-western coast of England. With regard to the latter, the great help which Raffaele's Mediterranean researches give to workers in the embryology of the Teleosteans of that region is, as Mr. Cunningham has observed, a sufficient proof of the close resemblance of the faunas.

That a connection should exist between the western Irish and Scandinavian fish-faunas appears, at first sight, less remarkable, since both belong to the North Atlantic. Accordingly it does not seem to have been the subject of special

\* *Ann. Mag. Nat. Hist.*, 1889, p. 415.

† *Journ. Marine Biol. Assoc., N. S.*, vol. i., p. 306.

comment. However, if we can prove that our western coast is the meeting-place of the two faunas,\* it may be of more interest.

The littoral waters having been fairly well explored, we hardly expected to be able to add much to our knowledge on this point, and our discovery of *Aphia pellucida* and *Crystallogobius Nilssonii*, though interesting as additions to the Irish list, only seems to show that these forms, common to Norwegian and Mediterranean waters, are, as might be expected, not absent from the intermediate localities. The latter, indeed, has since been found to be very abundant on the eastern and south-western coasts of England.

Unquestionably a more important addition to the Irish list is that of *Gobius Friesii*, a species only known hitherto from Scandinavian waters, and the capture of no less than four examples of *Arnoglossus Grohmanni* is not without interest, since it serves to prove that this Mediterranean fish, of which only two examples had previously been taken in British waters, is more generally distributed than was supposed. *Rhombus norvegicus*, a Scandinavian form which we were able to add to the Irish list, had already been recorded from a more southern point in English waters, and has since been found to be rather plentiful on the coast of Cornwall.

When we turn to the deep-sea fishes we get more interesting, or, at least, more novel results. So much yet remains to be done in the field of deep-sea exploration that we are not warranted in insisting too strongly upon the localization of species living at a depth where the climatic conditions of the surface are little, if at all, felt; nevertheless, making use of such knowledge as we possess, the mixture of northern and southern species in the composition of the bathybial fish-fauna of our western coast is very striking. Thus, from the south we have *Centrophorus squamosus*, *Pomatomus telescopium*, *Hoplostethus mediterraneus*, *Gadus argenteus*, *Macrurus æqualis*, *M. lævis*, and *Rhombus Boscii*, as it were in the same haul with the northern *Gadus Esmarkii*, *Haloporphyrus eques*, and *Macrurus rupestris*, not to speak of other forms more generally known.

*Scorpcæna dactyloptera* and, perhaps, *Macrurus cælorhynchus* are forms which have been found both in Norwegian and Lusitanian waters, while *Argentina sphyrcæna* seems to be fairly cosmopolitan. *Pristiurus melanostoma*, a common littoral form in the Mediterranean, proves to be with us, as in Norway, confined to deep water. The same applies to a great extent to *Phycis blennioides*, although we certainly took one example in quite shallow water, and the species is known to occur in the North Sea at depths far short of one hundred fathoms.

Günther † was the first to direct attention to the fact that certain forms (*e.g.* *Gadus*, sp.) which inhabit the littoral region in the northern latitudes are

\* Professor Haddon has already called attention to the same fact in the case of certain groups of invertebrates.

† "Study of Fishes," Edin., 1880, p. 265.

also to be met with nearer the Equator, but only in the somewhat deeper regions in these more southern areas. The subsequent experience of ichthyologists has not only confirmed this, but has also, as we have seen, established the truth of an exactly converse phenomenon. Either condition renders it somewhat difficult to formulate the relationships of structure to vertical habitat in the case of fish which inhabit or cross the border-land dividing the deep-sea and littoral areas; but the coincidence of both phenomena throws great obstacles in the way of a satisfactory explanation of either.

The increase in pressure which accompanies increase in depth of water seems to have impressed Day with the necessity for some special structural provision in the case of physoklistous fishes, and he puts forward a conjecture that the larval physostomous condition may persist throughout life in such examples of a species, normally physoklistous and normally littoral, as are found inhabiting great depths.\* As a matter of fact, such provision (which has, moreover, no existence) is quite uncalled for, since we know by analogy that the objection is far from formidable. Thus, to take a common instance, every fisherman knows how readily the air-bladder of the ling (*Molva vulgaris*) is distended by even such a slight diminution of pressure as is brought about by hauling the fish up from a depth of only thirty fathoms, or thereabouts. Now, the vertical range of the ling is about 0·2 to 150 fathoms; and while we learn from Collett that young examples are rarely met with on the Norwegian coast at less than one hundred fathoms, a young fish has been observed by one of us, at St. Andrews, contentedly swimming in a shallow tidal pool.

It follows, therefore, that however much a sudden alteration of outside pressure may affect a physoklistous fish, the latter is quite capable of adapting itself under natural conditions to a very considerable vertical range. Indeed, had the enormous vertical range of some of the deep-sea fishes been present to Day's mind, he probably would not have ventured upon such a fantastic suggestion.

M. Vaillant, in the introduction to his discription of the ichthyological results of the voyages of the "Talisman" and "Travailleur," draws attention to the resemblance which exists between the bathybial fish-fauna of the regions explored by those vessels and the fish-fauna of the Polar waters. His remark, no doubt, refers rather to a resemblance of structure in the fishes inhabiting these two areas than to any general identity of the species composing the two faunas. We may so expand this proposition as to imply that the same type of specialization is associated indifferently with either an Arctic or a bathybial habitat, an implication which will be found to be borne out by the facts of the case.†

\* "Fish. Great Brit.," I., pl. lxxxviii.

† We refer to type of general confirmation, and not to such characters as the reduction of the eyes, or the development of luminous organs.

Now, if the occurrence of northern littoral forms in the deep-water of the southern region were the only instance of a change of vertical habitat in relation to latitude, it might readily be assumed that the temperature was the consideration which drove the northern forms into deeper water, since, as is well known, the abysmal regions are practically unaffected by the surface temperature. Hence we might conclude that such-and-such a species was intolerant of great heat, and varied its vertical habitat accordingly.

But, although there may be a measure of truth in this theory, the occurrence of southern littoral forms only in the deeper parts of more northern seas, prevents us from accepting it as an entirely satisfactory explanation, and suggests the idea that it may be an equability of temperature throughout the year which is the desideratum, rather than any particular degree of heat or cold.

There is, however, an interpretation which appears to us infinitely more probable than any that can be deduced from conditions of temperature alone, and that is, that the struggle for existence drives the feeblest forms to the least desirable localities. The principle can, of course, be only very broadly interpreted, since not all the northern forms are feeble, nor do all the deep-sea fishes show signs of being descended from ancestors which were feebler than those which maintained their position nearer the shore.

It is, indeed, not necessary to assume that the bathybial forms of the present day have descended from fish which differed to any appreciable extent from their more successful competitors, since we know that in an aquarium there will always be found, among a number of fish of one species, which are to all appearance equally capable of taking care of themselves, some which manage to get most of the food, and some which fail to obtain their share, and so fail to grow at the same rate as the others. The reason, no doubt, lies in some congenital defect (whether mental or physical) which is not apparent to our intelligence; and we may assume that, in order to maintain an existence at all, such individuals migrated into regions of less competition, and (the process of evolution conforming to the changed conditions of environment) begat a race of descendants which ultimately came to exhibit characters of a degenerate order, if judged by the requirements of littoral life.

We do not, of course, claim originality for this proposition, which will be recognised as practically a recapitulation of Moseley's theory of the evolution of the bathybial fish of the present day, but we suggest that the resemblance of the Arctic to the bathybial fish-fauna is explicable on the ground that it has been brought about by precisely the same cause, viz. a migration to a more barren region. The resemblance disappears when we come to characters which have a distinct relation to bathybial requirements, such as the reduction of the eyes and the development of luminous, and of the presumably tactile, organs.

Why such a form as *Phycis blennioides* or *Pristiurus melanostoma* should be able to compete on equal terms with the littoral fishes of the Lusitanian region, and should fail with those which inhabit our own shallow waters is not apparent; but we certainly think that competition, not temperature, has consigned them to the deeper regions of our own sea, there to propagate, it may be, a race of typically abysmal descendants.

It is obviously impossible to formulate a rule which shall be applicable to all species alike, since we find that the conditions of latitude (and of competition) which admit a comparatively bathybial species, to littoral waters, are actually those under which another species (able to maintain its littoral position wherever it is found) reaches its greatest size. Thus the Witch (*Rh. megastoma*) inhabits only the shallow waters of the Iceland coast instead of the surrounding depths, while, under similar conditions of life, the Plaice (*Pl. platessa*) attains its greatest known size.

Indeed, in considering these matters, it is evident that we must take into account, not one condition or series of conditions (whether physical, competitive, or otherwise), but every condition which can possibly affect the species; and for this purpose the necessary information is lacking, and may, perhaps, never be accumulated.

It is, therefore, with a full consciousness of the inadequacy of our knowledge and of the probable imperfection of our conclusions that we have ventured to make the above suggestions. We may recapitulate them thus: that though, no doubt, there is a degree (whether of cold or heat) beyond which fish of a given species cannot exist, the cause that governs a change of habitat in accordance with latitude is mainly one of competition, and not of temperature.

In concluding our introductory statement, a few words are necessary as to the arrangement and classification of the forms dealt with. In selecting species for illustration we have sought to figure such as have not already been depicted in works dealing with British or Irish zoology, since our treatment of the material is, in a sense, national, in accordance with the wishes of the Society's Council. It follows that several forms, of which good drawings already exist, either in works of general zoology, such as the "Challenger" Memoir, or in foreign literature, are again figured here. We have also endeavoured, by the insertion of generic diagnosis, where required, to identify fish belonging to genera not already described in the literature of British ichthyology, and whenever we have found no reason for alteration, we have simply reproduced the diagnosis of previous authors, with due acknowledgment. It will be noticed that the classification we have employed differs from that adopted by one of us in the reports published in the "Scientific Proceedings" (vol. vii., N. S.. Pt. iv.). In these reports, which are more or less popular in character, it seemed advisable to deal

with the fishes in the order given by Day, in his "Fishes of Great Britain and Ireland," as the most reliable work on British ichthyology accessible to the general public. In the present case there is not the same need, and we have therefore adopted what seems to us the most natural classification, which is practically that of Dr. Günther.

We have considered it undesirable, in the case of most species, to incumber the descriptions with a complete list of references, and have therefore eliminated all that appear to be of only minor importance. It must also be understood that in no case do we hold ourselves responsible for the correctness of the synonymy given by the authors referred to. In the case of forms which are only treated in respect to their vertical or horizontal distribution we have referred only to such records as are concerned therewith.

## ELASMOBRANCHII.

### HOLOCEPHALA.

Genus *Chimæra*, Linnæus.

*Chimæra monstrosa*, Linnæus. The Rabbit Fish, or King of the Herrings.  
(Deep-sea.)

- Chimæra monstrosa*, . . . GÜNTHER, "Cat. Fish. Brit. Mus.," viii., p. 350;  
"Chall.," xxii., p. 12; "Ann. Mag. Nat. Hist.,"  
1889, p. 415.  
" " " " " DAY, "Fish. Great Brit.," ii., p. 286.  
" " " " " VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 80.  
" " " " " HOLT, "Sci. Proc. Roy. Dub. Soc., vii., p. 121.

This fish is represented in the Survey collections by five examples, taken in July, 1890, off Achill Head, at 220, 175, and 144 fathoms. It was previously known as a British form from specimens taken by the "Knight Errant" and "Triton" between the Shetland and Farøe Islands, at a maximum depth of 516 fathoms, and from an egg-case taken by the "Flying Fox," at 315 fathoms, off the S. W. coast of Ireland. We have received a skull, entangled on a hook to the W. of the Farøe Islands, and the occurrence of two examples between 70 and 135 fathoms to the north of the Great Fisher Bank has been recorded by one of us ("Journ. M. B. Assoc.," N. S., iii., p. 120). Another example, now in the British Museum, has reached our hands from comparatively shallow water on the south coast of Ireland. Four small specimens were taken by the French scientific expedition in the Bay of Biscay at depths of 433 to 670 fathoms. The

species is also known from the coast of Norway and from the Mediterranean, from the Cape of Good Hope and Japan, and has thus a very wide horizontal range. As to the vertical range, the greatest depth of which we have seen a record is 516 fathoms (Farøe Channel), while our Iceland specimen, trawled at a depth which certainly did not greatly exceed 40 fathoms, is, perhaps, the only one certainly known to have been caught in littoral waters, exclusive of specimens cast ashore by storms or found floating at the surface. The Rabbit-fish, however, doubtless occurs not unfrequently above the 100-fathom line, though the finding of its egg-case demonstrates that, as Dr. Günther has suggested, propagation takes place normally in deep water.

The species is sufficiently well known, to obviate the necessity of a description in this Paper, but our examples illustrate a condition to which attention has not hitherto been directed.

In a male measuring 12 inches from the snout to the origin of the second dorsal, that fin arises at a distance from the true base of the first dorsal\* equal to the length of the said true base. The posterior rays of the first dorsal are bound by membrane to the dorsum, so that there is formed an apparent base which extends to the origin of the second dorsal, and when the first fin is depressed about one-third of its spine extends beyond the origin of the second.

In a male of 15 inches from snout to second dorsal the true bases of the two fins are separated by an interval one-fourth longer than that of the first; and in a female of 16½ inches (measured in the same way) the interval is twice as long as the true base of the first fin.

These examples, therefore, show an interval between the apparent base of the first and the commencement of the second fin, but the two fins are connected by a fold of skin. This is usually hidden in a groove of the dorsum in spirit examples, and we are not aware that its existence has been previously noted.

In comparing our examples with a series, of various sizes, in the British Museum, it is apparent that the separation of the dorsal fins is a feature which becomes more marked with the growth of the fish, but not in a degree that can be exactly formulated.

Dr. Günther, in comparing *C. monstrosa* and *C. affinis*, Capello, includes the whole apparent base of the first dorsal in remarking ("Cat." viii. pp. 350–351) that the second dorsal in the Portuguese species is removed from the first by a space equal to the base of the latter. This is evident from the figure given by Capello ("Journ. Math. Phys. Nat. Lisb." iv. 1868), to whom Günther refers as the authority for his statement. A further statement that the pectorals in *C. monstrosa* attain to the posterior extremity of the pelvics must be modified in view of the

\* The base of the spine is included in this measurement.

condition exhibited by the specimens before us, in which the pectoral extremities are considerably short of those of the pelvis.

Judging by the variation which we have shown to exist in the interspace between the dorsals, this character may not always avail to distinguish between *C. monstrosa* and *C. affinis*, but the great space existing between the pectoral and pelvic in *C. affinis*, causing the former to terminate much in advance of the latter, at once separates the Portuguese species from any other that has been described.

## PLAGIOSTOMATA.

### SELACHOIDEI. Sharks

#### Fam.—CARCHARIIDÆ.

##### Genus *Galeus*, Cuvier.

##### *Galeus vulgaris*, Fleming. The Tope. (Deep-sea.)

*Galeus vulgaris*, . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., p. 219.

Examples were trawled at 154 fathoms, off the Coast of Mayo, on the 20th April. The tope was also met with in abundance in shallow water, usually in company with *Acanthias vulgaris*, and sometimes with *Scyllium canicula*. Though we believe that all three species are commonly caught by line-fishermen on the Farøe "Banks" at depths exceeding 100 fathoms, we know of no record earlier than that referred to above, which definitely includes them among the deep-sea fishes.

#### Fam.—SCYLLIIDÆ.

##### Genus, *Scyllium* Cuvier.

##### *Scyllium canicula*, Cuvier. The Lesser-spotted Dogfish. (Deep-sea.)

*Scyllium canicula*, . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., p. 219.

At 154 fathoms off the coast of Mayo. Common in littoral waters.

Genus **Pristiurus**, Bonaparte.**Pristiurus melanostoma**, Rafinesque. The Black-mouthed dogfish. (Deep-sea.)

- Pristiurus melanostomus*, . . . DAY, "Fish. Gt. Brit.," ii., p. 314.  
 " " . . . COLLETT, "Nyt. Mag. f. Naturvid.," xviii., p. 117.  
 " " . . . GÜNTHER, "Ann. Mag. Nat. Hist.," S. 6, vol. iv.,  
 p. 415.  
*Pristiurus melanostoma*, . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 121,  
 219.

A young specimen was trawled at 144 fathoms, 30 miles off Achill Head, on 4th July, 1890. Three mature examples were taken on the lines at 154 fathoms, 28 miles off Achill Head, on 20th April, 1891, and another at 250 fathoms, 45 miles off Black Rock, Co. Mayo, on 12th May, 1891. Considering the limited extent of our fishing operations below the 100-fathom line, it seems probable that the species is fairly abundant in the deep waters off the west coast. It was never encountered in shallow waters during the survey; and such accounts as exist of its capture at various parts of the coasts of the United Kingdom give no particulars of the depths. A single young specimen was taken by the "Flying Fox" at 150 fathoms (Günther), while on the Norwegian coast it has been recorded from 250 fathoms (Collett). Thus though the Black-mouthed dogfish has most probably been occasionally met with in comparatively shallow water in the British area, the balance of the evidence seems to show that it is on the whole a deep-sea fish in the Northern parts of the Atlantic, whereas it is well known as a common littoral form in the Mediterranean.

Fam.—**SPINACIDÆ**.Genus **Acanthias**, Risso.**Acanthias vulgaris**, Risso. The Picked Dogfish. (Deep-sea.)

- Acanthias vulgaris*, . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., p. 219.

At 154 fathoms, coast of Mayo. Common in littoral waters..

Genus **Centrophorus**, Müller and Henle.

“Two dorsal fins, each with a spine, which is sometimes hidden below the skin; no anal fin. Trunk elongate, without lateral folds. Mouth wide, but slightly arched; a long, deep, straight, oblique groove on each side of the mouth. Teeth of the lower jaw with the point more or less inclined backwards or outwards. Upper teeth erect, triangular, or narrow, lanceolate, with a single cusp. No membrana nictitans; spiracles wide, behind the eye. Gill openings narrow.” (Günther.)

**Centrophorus squamosus**, Gm., Linn. (Deep-sea.)(Pl. XLIII., 1, 1*a*, 1*b*.)

- Centrophore écallieux*, . . . BROUSSONET, “Mem. Acad. Sc.,” 1780, p. 675.  
*Squalus squamosus*, . . . GMEL. LINN, vol. i., p. 1502.  
*Centroscymnus ? squamosus ?*, MÜLLER & HENLE, “Plagiostomen,” p. 90. pl. xxxiv.  
*Centroscymnus squamosus*, . . . BOCAGE & CAPELLO, “Peix. Plagiost.”; “Proc. Zool. Soc. Lond.,” 1864.  
*Macephilus dumerili*, . . . JOHNSON, “Proc. Zool. Soc. Lond.,” 1867, p. 713  
*Centrophorus dumerilii*, . . . GÜNTHER, “Cat. Fish. Brit. Mus.,” vol. viii., p. 423.  
*Centrophorus squamosus*, . . . GÜNTHER, “Cat. Fish. Brit. Mus.,” vol. viii., p. 422.  
     “                    ”          . . . VAILLANT, “Exp. Sci. ‘Travail.’ ‘Talism.’ Poiss.,”  
   Paris, 1888, p. 75.  
     “                    ”          . . . HOLT, “Proc. Roy. Dub. Soc.” vol. vii., p. 219.

*Remarks on the Synonymy.*—We have followed Vaillant, the latest writer on this species, in considering the forms described as *C. squamosus* and *C. Dumerilii* as varieties of one species, since certain examples amongst those collected by the “Talisman” and “Travailleur” are described as presenting a mixture of those characters in virtue of which the species were originally separated. The matter is treated at greater length below.

DIAGNOSIS OF SPECIES.—*Scales*, small and sessile on the snout and fins, larger, pedunculate, and leaf-like, with posterior denticulations on the sides of the body; longer than broad, with a stout median keel projecting in front and behind, when viewed superiorly: a lateral keel on each side, variable, may be strongly marked,

when the denticulations of the posterior border are numerous and small, and the extreme lateral margins show traces of a secondary pair of keels; or may be feeble, the posterior denticulations being few and large; or may exhibit a condition between those described.

*Teeth* in upper jaw with a single sharp cusp, either narrow, the length of cusp much greater than the base, or broader, the outline of the cusp forming nearly an equilateral triangle. In the lower jaw the cusp is either narrow and almost perpendicular, or broader, with a well-marked lateral deflection. A median tooth usually present; absent only in extreme varieties. *Colour* uniform, either brown, inclining towards mahogany colour, or very pale, from chalky-white to blackish-grey. White specimens become a dull brown after immersion in alcohol. Iris black. Pupil clear emerald-green.

Dr. Vaillant, in his remarks on the "Talisman" and "Travailleur" collections (*op. cit.*, p. 69), pointed out, for the first time, that those forms which had hitherto been described as *C. squamosus* and *C. Dumerilii* are in reality only varieties of one species, to which the older name, *C. squamosus*, must, of course, be applied, while *C. Dumerilii* must be treated in future as a synonym. The amalgamation of the two forms is due to the occurrence, amongst the specimens which came under Vaillant's notice, of examples exhibiting intermediate characteristics. Vaillant has, unfortunately, not given any detailed information in regard to the particular features which influenced his decision; but the specimen examined by us gives in itself sufficient proof of the truth of his assertion, and we have accordingly constructed a diagnosis of the species which includes both forms.

There exists, unfortunately, some confusion as to the nomenclature of the two so-called varieties. *C. squamosus*, Gm. Linn., is founded on the *Centrophore écailleux* of Broussonet; but Vaillant, who has re-examined Broussonet's type specimen (a somewhat mutilated head), states that it is not the *C. squamosus* of later authors—notably Günther, in the "Catalogue of the Fishes in the British Museum," vol. viii., p. 422—but the *C. Dumerili* of Johnson.

The specimen examined by us bears in almost every particular the features of the variety, *i. e.* the *C. squamosus* of Günther and other late authors. In the vital particular of teeth, however, we find that, while exhibiting the broad cusps of the lower jaw strongly deflected outwards, in a manner quite in keeping with the other features of *C. squamosus*, Günther, a median tooth is present in both jaws. Median teeth are one of the most important distinguishing features of the type-species, the *Centrophore écailleux* of Broussonet and *C. Dumerili* of Johnson. We therefore second the amalgamation of the two forms which was proposed by Vaillant for reasons which probably are not less important than those noticed by that author.

The two varieties, taking the extreme development of the characters which

serve to distinguish them, present the following features, as most clearly described and illustrated (*op. cit.*, Pl. III.) by Vaillant:—

TYPE OF SPECIES.	VARIETY.
<p>"<i>Espèce typique</i>" (Vaillant).  <i>Centrophore écailleux</i>, Brouss.  <i>C. Dumerili</i>, Johns. (<i>et auctorum</i>).</p>	<p><i>C. squamosus</i>, Günther, Cat. (<i>et auctorum</i>).</p>
<p><i>Colour</i>.—Brown, more or less mahogany.</p>	<p><i>Colour</i>.—Blackish-grey.</p>
<p><i>Fins</i>.—Height of first dorsal nearly half the length of its base; height of second dorsal a half, or less than half, the length of its base.</p>	<p><i>Fins</i>.—Height of first dorsal less than one-third the length of its base; height of second dorsal more than half the length of its base.</p>
<p><i>Scales</i>.—Lamella nearly as wide as long, lateral keels strongly marked, posterior denticles fine, numerous.</p>	<p><i>Scales</i>.—Lamella considerably longer than wide, lateral keels feeble, posterior denticles large and few.</p>
<p><i>Teeth</i>.—In the upper jaw with narrow cusps; in the lower jaw with nearly vertical cusps; a median tooth present.</p>	<p><i>Teeth</i>.—In the upper jaw, with cusps forming almost an equilateral triangle; in the lower jaw, with cusps strongly deflected outwards; a median tooth present or absent.</p>

It may be further stated that the spines of the dorsal fins are stouter and more curved in the type than in the variety.

We may be allowed to call attention to the well-known fact that the development of a Plagiostomous fish is accompanied by very considerable changes in its dermal armature, which, moreover, is frequently different in the sexes. It follows, therefore, that great caution is required in distinguishing such species as depend for their separation chiefly on the characters of the scales and teeth. Whether in the case of *C. squamosus* there is any marked difference in the dentition of the two sexes is a matter as to which we have no information. All Vaillant's specimens were males, as is also our own, and we have seen no description of a female (specially described as such). Hence we must admit that possibly the diagnosis we have compiled may be applicable only to males.

The pedunculate or sessile character of the scale has been made the basis of a subdivision of the genus *Centrophorus*, which has not received much support from subsequent authors. As Vaillant points out, even those species which possess pedunculate scales have also sessile scales on some parts of their body; and we would even go further, and suggest that the pedunculate character cannot even be applied as a specific test at all stages of development. In the absence of any knowledge of very young forms this is mere conjecture; but it appears to us very possible that no member of the genus exhibits pedunculated scales when very young.

*Size.*—The maximum size recorded is 142 cm. (4 feet 8 inches), Bocage and Capello.

*Vernacular Names.*—At Setubal, Arreghonda (B. & C.); Arregonhada (Vaillant).

*DESCRIPTION OF SPECIMEN.*—Only a single example was taken during the Survey; it is an adult male. A sketch of it is given in fig. 1, Pl. v.

*Dimensions.*

	CM.	INCHES.
Total length, . . . . .	105	$41\frac{1}{2}$
Total length without caudal fin, . . . . .	93	$35\frac{1}{2}$
Tip of snout to eye, . . . . .	6	$2\frac{3}{8}$
„ „ to angle of jaw, . . . . .	12	$4\frac{3}{4}$
„ „ to base of pectoral, . . . . .	24	$9\frac{1}{2}$
„ „ to base of first dorsal spine, . . . . .	36.5	$14\frac{3}{8}$
„ „ to base of second dorsal spine, . . . . .	75	30
„ „ to commencement of first dorsal fin, . . . . .	38	15
„ „ to commencement of second dorsal fin, . . . . .	76.5	$30\frac{3}{16}$
„ „ to anus (cloacal opening), . . . . .	68.8	$27\frac{1}{8}$
Length of eye, . . . . .	6	$2\frac{3}{8}$
Length of pectoral fin, . . . . .	13	$5\frac{1}{8}$
Length of base of first dorsal fin. (without spine), . . . . .	10	$3\frac{1}{16}$
„ „ second „ „ „ . . . . .	6.5	$2\frac{9}{16}$
Greatest height of first dorsal fin, . . . . .	5.3	$2\frac{1}{8}$
„ „ second „ . . . . .	5	2
Width of interorbital space, . . . . .	4.9	$1\frac{1}{16}$
Width of intraspiracular space, . . . . .	7.5	3
Greatest height of body (from base of first dorsal spine), . . . . .	16.5	$6\frac{1}{2}$

*Proportions.*—The eye is equal in length to the snout; its length is greater than the width of the interorbital space, and less than the distance between the spiracles. The length from the tip of the snout to the last gill slit is contained about  $4\frac{1}{2}$  times in the total length (without the caudal), and is somewhat greater than the greatest height of the body. The extreme length of first dorsal fin is equal to  $2\frac{1}{3}$  times the height; in the second dorsal fin the length is  $1\frac{4}{5}$  times the height. The base of the second dorsal is two-thirds of the base of the first dorsal, which is one-third of the interspace between the two fins (spines excluded in these measurements). The extremity of the outer lobes of the pelvics are about opposite the base of the second dorsal spine, the extremities of the claspers opposite the middle of the base of the second dorsal fin.

*Shape.*—When newly caught the specimen presented a plump, well-rounded contour, with no marked trihedral aspect in section, such as characterises many ground sharks, though the ventral surface was slightly flattened. It has been

sought, so far as possible, to restore this condition in the sketch, since the action of alcohol had greatly shrunk the tissues by the time a detailed examination could be made.

*Fins.*—The extremities of the dorsal fins extend for a considerable distance beyond their respective bases, so that in the case of the second dorsal the extremity almost reaches the commencement of the dorsal lobe of the caudal, and overhangs a considerable part of the ventral lobe. Both dorsals are much alike in shape, the dorsal margin being convex in the anterior, and concave in the posterior region, each terminating in a narrow-pointed process parallel to the dorsum.

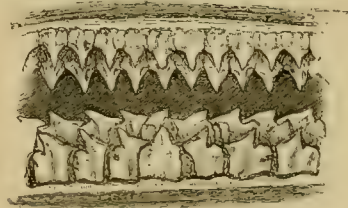
The dorsal lobe of the caudal, commences immediately behind the free end of the second dorsal. It rises gradually in height, and terminates in an expanded process, extending well beyond the posterior extremity of the vertebral column. We presume that this process is rounded (as represented in the sketch) under natural conditions; but in our specimen a portion is missing, so that the sketch must be regarded as, in this respect, a restoration. The ventral lobe commences opposite a point about midway between the end of the base of the second dorsal and the free extremity of that fin. It is roughly triangular in shape, but its posterior face is very irregular in outline (*vide* Pl. XLIII., fig. 1), and its base fails to reach the end of the vertebral column. The dorsal and ventral lobes are therefore quite unconnected in our specimen, though how far the latter conforms in this respect to the normal condition we are unable to say.

*Scales.*—These impart to the skin rather a velvety appearance when viewed from a certain distance. This is seen on close inspection to be due to the fact that the lamellæ, though overlapping each other, are at the same time somewhat outwardly directed. The scales on the anterior part of the head and on the fins are small and sessile. A group of scales from the side of the body is shown in fig. 1*b*, and a single scale is seen, as it appears in lateral view, in fig. 1*a*, which sufficiently illustrates the pedunculate character in that region of the body. On comparing fig. 1*b* with Vaillant's drawings (*op. cit.* Pl. III., figs. 2 and 3), it will be seen that the scales of our specimen appear to differ considerably in shape from either of those represented by the French observer; but this is due entirely to a slight difference in the point of view from which the figure was made. It will further appear that in the greater elongation of the lamella the agreement is rather with the variety (*C. squamosus*, Günth. et auct. plur.) rather than with the typical form. In the strength of the lateral keels, however, our examples are somewhat intermediate. So also with regard to the posterior denticles; for out of the group of four selected at haphazard by the artist, two show the few and bold denticles of the variety, whilst the other two, especially the most anterior one of the group, exhibit numerous and fine denticles. In scales, therefore, it appears that our Irish example is to some extent intermediate, but inclines, on the whole, chiefly to the condition of the variety.

*Eye.*—The emerald green pupil is very large, and in the fresh condition is the more conspicuous, since a great part of the black iris is hidden by a folding-in of the skin of the head.

*Labial folds* extend from the angles of the jaw for about one-third of the length of each side of the upper jaw, and are consequently somewhat widely separate from each other in the middle line.

*Teeth* in three vertical rows in upper, and two rows in under jaw. In the upper jaw the middle, in the under jaw the inner row appear to be chiefly functional. In the upper jaw there are 35 teeth in each transverse row, *i. e.* 17 on each side of a median tooth. In the under jaw there are 29 teeth in each row, 14 on each side of a median tooth. The annexed woodcut represents the central region of the mouth, seen from the ventral aspect. In this the median teeth are distinctly visible.



Central region of jaws of *Centrophorus squamosus*.

The presence of the median teeth in this specimen is of some interest, since the dentition, in other respects, is completely characteristic of the variety, as referred to above.

*Anatomy.*—Of the visceral anatomy it may be remarked that it does not differ in any essential degree from the familiar littoral Selachian type. Moreover, Günther's description ("Chall.," vol. xxii., p. 6) of the viscera of the Japanese *C. squamulosus* reveals an arrangement so much like the condition seen in our own example that one description might do for both, except for the fact that the specimen described by Günther was a ripe female, 27 inches long, whereas that now under consideration is a mature, but unripe male.

The testes are of equal size, situated on a level with the first dorsal fin, white in colour, and typically reniform in arrangement.

*Colour.*—When first brought to the surface our specimen was of a uniform chalky-whiteness, but shortly became darker, assuming a pale-leaden hue. The difference between such and the blackish-grey colour stated by Vaillant to characterize the variety seems unimportant, as it is evidently more the result of a greater or lesser degree of expansion of similar chromatophores than of any other distinction. In colouration, therefore, we may say that our specimen conforms to the variety rather than to the type. An attempt, in fig. 1, to reproduce on so small a scale something of the velvety appearance of the skin has resulted in making the fish look somewhat darker than it was in the living condition. The action of alcohol has now caused a dull-brown colouration of the skin, whilst, of course, the vivid green of the crystalline lens has entirely disappeared.

*LOCALITY AND DISTRIBUTION.*—Only one specimen was taken on a long line on May 24th, 1891, at a depth of 250 fathoms, 45 miles off Blackrock, Co. Mayo.

The species was not previously known as an inhabitant of the British area, nor is much information as to its geographical distribution available. It has long been known, however, as an inhabitant of the deep-water off the coast of Portugal, where, with other of its congeners, it forms the object of a regular fishery. This was first brought to public notice in this country by Dr. Perceval Wright, who had occasion to visit Setubal when endeavouring to verify the presence of *Hyalonema* in European waters. He has given (*Ann. and Mag. Nat. Hist.*, 1868, vol. ii., p. 426) an interesting account of his experiences, but the only species identified on that occasion was *C. cælolepis*. This led to an expression of opinion by Dr. Günther ("Chall.," vol. xxii., p. 5), that all the European members of the genus were inhabitants of deep water, and the results of the expedition of the "Travailleur" and "Talisman" have since shown that this is the case.

Dr. Vaillant himself took part in a fishing cruise in one of the boats engaged in the industry, and his account is of such interest that we make no apology for paraphrasing it at considerable length.

He remarks that the shark fishery at Setubal, of which *C. squamosus* is the commonest product, has been in existence from time immemorial, and constitutes a regular industry, though the number of boats engaged, viz. three at Setubal and about as many at Cezimba, is not considerable. The boats are about sixteen or nineteen feet long, broad, and strongly built, but are at the same time "balanced so as to yield to the slightest impulse of the water,"\* and therefore able to keep the sea in foul weather; this is the more advisable since the distance of the fishing-grounds often necessitates a trip of several days' duration, with a possible difficulty of making the harbour on return.

The particular boat selected by Dr. Vaillant for observation was manned by nine men and a boy.

The apparatus employed consists of lines, mounted at equal distances with cod-hooks on snoods about five feet in length, each line being about 97 feet long. From 20 to 40 of these lines are joined end-to-end, in the usual manner, so that from 400 to 800 hooks are employed at the same time.

The lines are shot from the bow, the boat meanwhile being rowed with a couple of oars—longer than those in ordinary use—in order to prevent fouling. The chief peculiarity of the operation seems to be that no buoys are used. The end of the line first shot is weighted with a couple of stones, whilst the last line is made fast to a cord about 700 fathoms long (termed by Vaillant a "maitresse corde"), one end of which is kept in the boat. From our own experience on board the "Harlequin" we can understand that this is a wise precaution, since, on the occasion when our *Centrophorus* was caught, although we were using

\* This description seems to suggest something of the build of a whale-boat, or Greencastle "yawll," with a good rake fore-and-aft.

buoy-lines of what we considered ample length, one of the buoys disappeared soon after it was shot, and we were only just in time to catch the other, and had to increase its buoyancy by the addition of an empty ten-gallon spirit-carboy in order to keep it at the surface.

The operation of shooting takes about an hour and a-half, and there is then an interval of about an hour and three-quarters before hauling. This last is the most difficult part of the whole business, as the means employed by the Setubal fishermen are decidedly primitive. A kind of derrick, consisting of a plank, with a pulley at the end of it, is made fast to the mast and the false stem; the "maitresse corde" is placed on this engine, and the crew, seating themselves in pairs on each thwart, haul it in hand-over-hand, whilst the skipper coils it up in the stern. It is about two hours before the first line makes its appearance, when it is immediately passed to the starboard quarter. Here it is hauled by three or four of the crew, whilst the skipper stands by with the gaff, and another man takes the hooks out of the fish, and stows away the lines ("sans grand ordre") as fast as they come in.

The whole operation (shot and haul) witnessed by Dr. Vaillant took five hours and a-half, the sea meanwhile being remarkably calm. The catch was twenty-one sharks and eight specimens of *Mora mediterranea*.

Vaillant remarks that the presence of sand made it evident that a greater part of the line had been on the bottom, and that, moreover, if the fish inhabited higher zones, experience would long since have taught the fishermen the folly of using so costly and cumbersome an engine as the "espinheis"\* for their capture. He also notes that there is on the coast a large population entirely engaged in fishing, and the fact that these sharks are never caught except in the manner described is a sufficient proof that they are exclusively confined to deep water.

That they have a considerable horizontal range was evident from the capture of a few small individuals belonging to some of the species fished for at Setubal, at points widely distant from each other, and he is no doubt right in attributing their scarcity in the collection of the expedition, as due not so much to their rarity as to an agility which ensures them a certain immunity from the trawl. The trawling operations of the "Harlequin" in the vicinity of the spot where our specimen was obtained do not throw much light on this subject, as in one haul the net was capsized, and in the other nothing but the beam and irons came to the surface.

Inquiries were made by Vaillant as to the profits arising from the Setubal shark fishery, and it would appear that these are very slight. The chief commercial product is the skin, obtained mostly from *C. granulosus*, which is suitable for manufacture into a kind of "galuchat" (equivalent, we suppose, to the English trade

\* A name applied by the Setubal fishermen to the apparatus described on account of the resemblance borne by the line and snoods to the "espinheis," or backbone of the fish.

term, "shark-skin"), this is of some little value. The skins of other kinds, however, including *C. squamosus*, are only fit for polishing wood, for which purpose the skin is dried and cut into long narrow strips. One such skin, the species being *Scymnis lichia*, was purchased by Dr. Vaillant for a franc and a-half, or thereabouts.

The liver yields an oil used by the country folk in their lamps, and particularly esteemed for the lubrication of wooden machinery. Finally the body of the fish is dry-salted and used for food just as our most familiar member of the family, *Acanthias vulgaris*, is used on the Cornish coast.

It is hardly to be wondered that Vaillant doubts how far such products would indemnify the cost of the gear and fittings necessary for such a fishery, and we have no reason to suppose that the inhabitants of the Mayo coast are ever likely to put the matter to a test; but there is no doubt, as Vaillant remarks, that similar gear might with advantage be used for scientific purposes, with a view to the discovery of forms not likely to be captured in trawls or dredges.

#### BATOIDEI. Rays.

#### Genus *Raia*, Cuvier.

##### REMARKS ON THE DIAGNOSIS OF SPECIES BELONGING TO THE GENUS *RAIA*.

The variation which is found amongst the species of this genus has proved a source of considerable perplexity and error to many observers.

The difficulty of identifying certain species is very great, and arises not only on account of the variation, but also because a custom has become established amongst writers to include in their diagnoses certain features which alter, to an extraordinary extent, according to age or sex. The relative convexity of the anterior margin of the disk, the arrangement of the dorsal and caudal spines, and the colouration and markings of the back may be taken as examples of the varying features referred to. The number of rows of teeth are generally looked upon as of paramount importance in the identification of species, but even here we find that considerable modification exists according to the age of the specimens examined.

It is therefore not surprising that in the descriptions of species from a limited number of examples at command, statements should have been made which in reality are applicable only to one sex at a certain stage in its existence, instead of applicable to the species as a whole.

When comparing mature examples of any species, a marked difference may at once be detected between the males and the females. The presence of claspers, and alar spines in the males alone, have always been recognised by writers, but

with a view of drawing attention to certain less conspicuous, but equally important differences occurring not only between males and females but between old and young specimens of the same species, the following observations have been introduced :—

(a) *The Relative Convexity of the Anterior Margin of the Disk.*—This feature is generally referred to as of specific value, without much reference as to the maturity or sex of the examples described. Day,\* for instance, in dealing with *R. batis*, says:—"The anterior edge of the disk undulated and deeply emarginate below a line drawn from the end of the snout to the angle of the pectoral fins." A similar statement is made with regard to *R. macrorhynchus*, *R. alba*, *R. æghrynychus*, *R. fullonica*, &c., and in none of these cases are we told the size or sex of the species to which the statements are applicable. In the case of *R. alba* we are indeed told that "In young specimens the disk is not so undulating along its border as in adults;" but again, we are left in ignorance as to the sex of the young specimens. Moreover, his description of the adult *R. alba* has in all probability been drawn up from a male example, which, following the course to be observed in all Raüdae, has a more deeply concave margin than the adult female. Even yet we may not conclude that his young specimen was a female, because young specimens of both sexes show less concavity in their anterior margins than adults.

(b) *The arrangement of the Dorsal and Caudal Spines.*—The dorsal and caudal spines, or dermoid denticles, are invariably arranged in rows, and may be spoken of as "linear spines." They form, in their arrangement, a conspicuous feature in the appearance of different species of the genus Raia.

Spines are also found conspicuously on the snout, and round the orbits. In certain species (*R. clavata*, *R. radiata*) spines are scattered over the dorsum of the disk, but in the majority of cases the denticles found in this situation are insignificant, and they are never arranged in any definite order. We find it convenient to term these lesser denticles "spinules." They are stronger and more conspicuous in the female than in the male, except in the case of *R. radiata*, where the spines of large size are freely distributed over the dorsum, and where it may be said that no difference, in spinulation, exists between the sexes.

Spinules are present on the tail also, scattered between the linear spines, or formed into a sub-marginal border. The latter condition is seen in *R. circularis*, adult *R. alba*, *R. radiata*, and *R. microcellata*. In the description which follows as to the caudal spines these spinules are not considered.

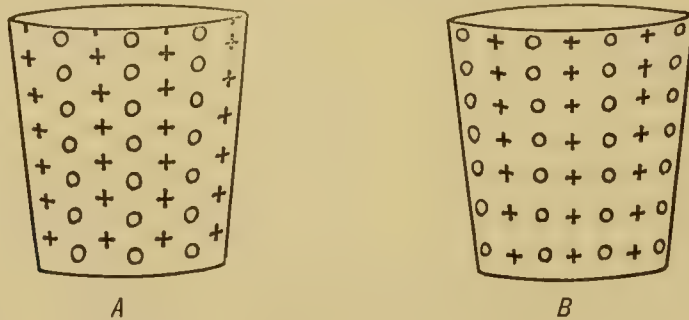
One other point must be noticed before treating the arrangement of the spines. Apart altogether from the alar spines already referred to as prominent only in mature male, it is interesting to notice that as sexual maturity is reached, *i.e.* as

\* Day, "British Fishes," vol. ii., p. 336.

the claspers are elongating, and the alar spines (which are possibly erectile) are becoming conspicuous, the spinules along the anterior margin of the disk begin to develop rapidly. When the claspers are fully elongated, these spinules, much stouter than their fellows, form a band extending from the snout, to each angle of the pectoral fins.

The linear spines, when studied with reference to the gradual growth and development of any one species are found to be subject to regular changes. So much is this the case, that in diagnosing a species, writers have constantly been compelled to make their statements capable of considerable elasticity of interpretation.

*R. maculata* must be described as possessing a central row of spines along the back and tail, with one row or two rows on either side. In some cases the central row is less prominent than the side row or rows; in other cases the side rows are only represented by a few isolated, but large spines.



DIAG. 1.—*A* represents a section of the tail of a very young specimen, two and a-half inches across, and *B* a section from the tail of a specimen eight inches across. It will be noticed that in *B* the position of the rows of signs has been reversed, the central row being in *A* o and in *B* +.

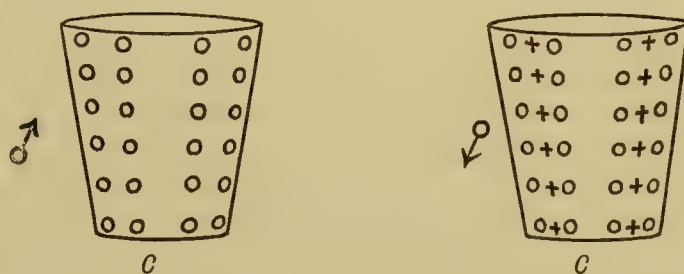
In *R. circularis*, at all stages, the tail is found to be possessed of many rows of spines; yet if a progressive series of examples be examined, a very instructive system of alternation is discovered.

In very small specimens of about  $2\frac{1}{2}$  inches across the wings, the whole surface of the disk is more or less spinous, so as almost to resemble the condition seen in *R. radiata*—a ray which does not occur in Irish waters, so far as present records show us. The tail has a row of strong and prominent spines down the middle line, but on the disk the difference between spines and spinules is not yet great. On either side of this median row there is, at the root of the tail, a row of insignificant spines. These cease on a level with the posterior margin of the pelvic fin. On the outer side of each of these again comes a row of strong well-marked spines, which run from the sides of the triangular patch in the centre of the back to the end of the tail. Again, outside each of these rows there is a row of feeble spines, which, about half-way along the tail, assume the extreme lateral

position. There is therefore a regular alteration of rows of strong and feeble spines.

If now we observe the condition of these rows as the size of the fish increases, we notice that gradually, the spines which were large become insignificant, and *vice versa*. This change may, perhaps, be more readily understood by a comparison of diagrams *A* and *B*, where in each case the large spines are marked *o*, and the small spines *+*.

By a continuation of the same process the arrangement of the spines still alters. The small spines (*+*) of *B* become more and more reduced in size, and the central row gradually disappears. The ray is now about 12 inches in transverse measurement, according to our Irish specimens. The other small spines also become reduced, and when a condition of sexual maturity is reached we find that, in accordance with what has already been said as to the female being the more spinous sex, the small spines of the male disappear rather more rapidly than those of the female. In this manner a sexual difference becomes established in the adults, which may be illustrated in the following diagram:—



DIAG. 2.—Sections of tails of male (♂) and female (♀) *R. circularis* in adult condition.

The central row of spines is absent in both cases, and in the male all small spines have disappeared. In the female the row of small spines is still indicated. This row, however, does not extend in old specimens more than halfway along the tail.

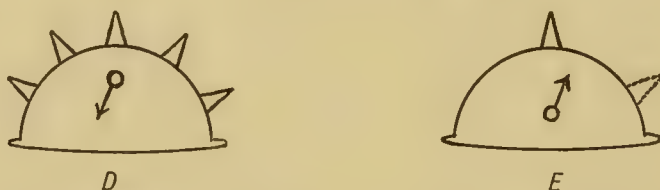
Owing to the rate of growth being subject to considerable variation in different localities, it may very readily happen that the size (12 inches) given above for the disappearance of the central row of spines is too small, that in other localities, as the North Sea, the rays may be larger before this row disappears. The size, as stated, however, seems to represent a fair average in regard to Irish specimens. At the same time there is, in the large collection of rays and skates under review, a specimen of 12 inches—a female, which has still a distinct central row. The specimen has no alar ocellus, or circular spot on the wings, and will be referred to again.

Another species which shows, to a marked extent, the variation which exists amongst the linear spines, is *R. microcellata*. The female shows a condition

what similar to that seen in a young male, *R. circularis*; but if adults of both sexes be examined, a much greater contrast is found than exists in adult *R. circularis* as seen in fig. *C*. Taking a transverse section of the tail in both sexes, we present figs. *D* and *E*.

(c). *Coloration, and markings of the skin*.—It is a matter of common knowledge that colour variation, so frequently met with in fishes as a whole, is, at least, as frequent amongst the *Raiidæ* as in any other group. Nevertheless we invariably find a more or less precise statement of the pigmentation included in diagnoses of the species of this family. To eliminate such altogether is by no means desirable, but it is certainly necessary to allow great latitude of interpretation to existing descriptions.

The names *R. alba* and *R. maculata* indicate that both general colour and particular markings have been considered characteristic features of certain species; and in the case of *R. alba* we know that the dead whiteness of the ventral surface, which is certainly characteristic of the adult, has been found to be constantly



DIAG. 3.—*D* represents the condition found in adult females—one row of median spines, with two rows on each side. *E* is produced from nine examples of adult males, seven of which possessed the median row of spines alone, the other two specimens having, in addition, a few isolated spines on one side. The latter are indicated by the dotted spines.

diversified by bands of brown in the young. In *R. maculata*, again, we have observed a specimen in which the spots were wholly absent. The alar ocellus, which is so conspicuous in the Cuckoo Ray, is represented to a greater or less extent in the young stages of nearly all species of *Raia* which have come under our notice; and since it may be either very conspicuous or hardly discernible in the adult condition of a single species (*e.g.* *R. maculata*), it is evidently a character which should not be very strongly insisted on in specific diagnosis.

The whiteness of the ventral surface which characterizes the living condition of a great many rays is subject to considerable *post-mortem* changes, since it may become grey, or even brownish, when the fish has been dead for some time. *Post-mortem* changes are also noticeable in the general texture of the skin, owing at least in great measure to the drying influence of the atmosphere. Thus, a fish which, when fresh, appears perfectly smooth both to sight and touch, may be found, when stale, to be covered with minute asperities, imparting to the skin a distinctly granular appearance; and it seems very probable that a want of

appreciation of this circumstance has given rise to some of the existing confusion in the arrangement of the genus.

(*d.*) *The Teeth*.—That the shape of the teeth varies according to the sex of the individual in several members of the genus is a fact to which reference has frequently been made, yet it has been too often left to the reader to discover for himself that this statement is often only applicable to adults. A young male, in fact, possesses teeth which usually differ in no important respect from those of a female, and it is only with the assumption of sexual maturity, *pari passu*, with the elongation of the claspers, that the teeth begin to show the elongated and pointed characters which are so conspicuous in the adult males of some species. Even in the several long-nosed species, which have the teeth pointed in both sexes, the points are slightly the longer in adult males. It seems therefore by no means improbable that these structures subserve some definite function in connection with sexual activity.

The number of rows in which the teeth are arranged is a character usually made use of in specific diagnosis; but it is one which possesses absolutely no value unless the size of the specimen is also stated, since the number varies with the age or size of the individual. As far as we are aware, such information is nowhere forthcoming. The result is therefore rather confusing. The difference in the number of rows at different stages may be illustrated by the statement that whereas a full-grown Homelyn (*R. maculata*) has over 50 rows, an example of the same species only 4 inches across the disk has less than 30 rows. Again, it is not invariably stated which jaw is referred to in the enumeration, but this is not of great importance since the number does not differ very greatly. However there are usually a few more rows in the lower than in the upper jaw.

***Raia batis*, Linnæus. The Grey Skate. (Deep-sea.)**

- Raia batis*, . . . STROM, "Norsk. Vid. Selsk. Skrift.," 1881, p. 80; 1884, p. 46.  
 ,, ,, . . . COLLETT, "Nyt. Mag. f. Naturvid.," xviii., p. 119.  
 ,, ,, . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 121, 219.

A small example was trawled on the 4th July, 1890, at 220 fathoms off Achill Head. Two, measuring 28 inches in length, were taken on 10th July, 1890, at 500 fathoms in the same neighbourhood, as was also a fine specimen of 54 inches, on 20th April, 1891, in 154 fathoms. None of these specimens were preserved, but they were carefully examined by one of us at the time of capture, and belonged, without doubt, to the species indicated. It is noteworthy that *R. circularis* is the only ray which has been found at a depth exceeding 500 fathoms. The grey skate has been taken on the Norwegian coast at a depth of 150 fathoms, and,

though the fact has not been definitely recorded, certainly occurs on the Farøe “banks” at depths exceeding 100 fathoms. As it is common in shallow water, it appears to have a vertical range practically coterminous with that of the Batoidei as a whole.

***Raia oxyrhynchus* (Linn.).** The Long-nosed Skate. (Deep-sea.)

<i>Raia oxyrhynchus</i> , . . . .	LINNÆUS, “Syst. Nat.,” i., p. 395.
“ “ . . . .	GÜNTHER, “Cat.,” viii., p. 469.
“ “ . . . .	DAY, “Fish Great Brit.,” ii., p. 341.
<i>Raia chagrinea</i> , . . . .	YARRELL, “Brit. Fish” (ed. 1), ii., p. 414.
<i>Raia vomer</i> , . . . .	GÜNTHER, “Cat.,” viii., p. 468.
“ “ . . . .	COLLETT, “Forh Videns,” 1879, p. 106.
“ “ . . . .	LILLJEBORG, “Sverig. o. Norg. Fish.,” iii., p. 598.
“ “ . . . .	YARRELL, “Brit. Fish” (ed. 3), ii., p. 548.
<i>Raia rostrata</i> , . . . .	RISSE, “Ich. Nice.,” p. 7.
<i>Raia salviana</i> , . . . .	MÜLLER & HENLE, p. 143.
<i>Raia mucronota</i> , . . . .	YARRELL, “Brit. Fish,” (ed. 2), ii., p. 550.
“ “ . . . .	COUCH, “Cornish Fauna,” p. 25.

DIAGNOSIS OF SPECIES.—The width of the disk about one-tenth greater than its length; the anterior margin deeply concave. Outer angle of pectoral fin somewhat pointed. Snout much elongated and pointed, contained about three times in the width of the disk. Eyes elongated and flattened; in young examples about equal to width of inter-orbital space, which, in adults, equals the combined length of the eye and spiracle. Supraorbital ridge inconspicuous. Spiracles small, measuring transversely half the length of the eye. Distance from tip of snout to lateral angle of mouth equal to distance from same point to posterior margin of eye. Teeth pointed in both sexes, with a central keel, which is inconspicuous in young examples.

No large spines on disk. Tail with a row along each lateral edge,\* and a median row, which is incomplete or absent in large examples. Both upper and under surfaces of the disk and tail covered with small spinules, but in young specimens the greater part of the upper surface is smooth.

Colours grey or greyish brown superiorly, frequently with a few whitish and dark-brown spots or streaks. The under surface a dark grey.

The long-nosed skate appears to occur with the greatest frequency off the coast of France and in the Mediterranean. It has been taken as far south as Madeira.

\* These rows are probably absent in very young specimens, a central row being conspicuous.

We are able to record it, for the first time, from the coast of Iceland and from Rockall, whence it seems to be one of the commonest rays. It occurs occasionally during the spring and summer months at Plymouth and along the coast of Cornwall, but appears to frequent deeper water than the other skates usually landed on our coasts, and probably on this account is the more seldom seen. It has been recorded from the coast of Yorkshire, and from Norway, but is certainly rare in the North Sea. It seems to be generally distributed along the west coast of Ireland, but previous to the survey there existed no record of the capture in Irish waters of any fish which could with certainty be identified with this species.

The examples recorded by Thompson,\* and more recently by Mr. Paterson,† if correctly identified with *R. oxyrhynchus* (Montagu) were in reality *R. alba* (Lacip), and Mr. Paterson's record of *R. mucronata*, a synonym of the species now under consideration, is admittedly doubtful.

The species is most easily recognised by reason of the feature to which its ordinary name applies, the long nose and deeply concave anterior margins of the disk.

During the Survey, a large specimen, measuring 50 inches in length, a female, was captured 30 miles off the coast of county Mayo. The trawl was let down on the rapidly deepening slopes of the continental plateau in 500 fathoms and hauled up in 375 fathoms. Other specimens, all immature, were taken in 25, 31–38, and 74–80 fathoms. The 50" specimen measures 34 inches across the wings, which is also the measurement from the tip of the snout to the posterior extremity of the pelvic fin. Both sides of the disk and tail are covered with spinules, which point in a backward direction. These spinules are least prominent in the centre of the dorsum and most conspicuous on the under surface of the snout and head. The interorbital space is flat, and, like the median dorsal region generally, has a worn appearance. Round the inner side of the orbits, however, and especially in front of these organs, the spinules are again conspicuous. There is no trace of any spine on the disk. The spinules continue, without interruption, along the surface of the somewhat flattened tail. About an inch and a-half behind the posterior margin of the pelvic fins, on both sides of the tail, a row of conical spines make their appearance, and continue backwards, along the extreme lateral margin, to the level of the second dorsal fin. In the median line of the tail are the degenerate remains of two spines. Both are now mere flattened bases, partially buried in the skin, and might be readily overlooked.

Another large female, taken off Gregory Sound on the 8th April, 1891, belonged to the same species. It measured 53 inches in total length, the width and

\* "Nat. Hist. Ireland," vol. iv. p. 259.

† "Birds, Fishes, and Cetacea of Belfast Lough." Lond., 1881, p. 228.

length of the disk being, respectively, 36 and  $31\frac{1}{2}$  inches. The snout was 12 inches long, or exactly one third of the width of the disk. The weight was 32 lbs. The colour different from that of the last specimen, only in the presence of some irregular roundish lighter blotches on the upper surface, a difference of small importance under any circumstances, and of none at all when, as in the present instance, the variegated example came from only 38 fathoms, and the uniform example from some depth between 500 and 375 fathoms. There is no important difference in proportions between the two, but the spinulation differs in the entire absence of median caudal spines from the larger specimen. The lateral row is also wanting behind the level of the centre of the first dorsal.

Seeing that in the 50-inch specimen the median spines had almost disappeared, it is not surprising to find no trace of them in a fish 3 inches longer; yet the distinction between *R. oxyrhynchus*, and *R. vomer* seems to be based on the respective presence and absence of these spines. The two species were amalgamated by Day, but Lilljeborg, a more recent author, admits *R. oxyrhynchus* to the synonymy of *R. vomer*, only with the prefix of a note of interrogation. We venture to think that the observations recorded above most fully confirm the correctness of Day's opinion, and since, as we have noted in our introductory statement on the *Raiidae*, the adult male is almost invariably less spinous than the female, we think it likely that males may lose the median spines earlier than is the case with females. Unfortunately no notes were made on the spinulation of the males, nor were any preserved, but a large male was examined and measured by one of us on the same date as the female of 53 inches, and, in the absence of any note to the contrary, we are, perhaps, justified in inferring that it did not differ from the female in a character so important as that of the median spines. The total length of this example was 48 inches, the length and width of the disk 29 and  $33\frac{1}{4}$  inches, and the length of the snout  $10\frac{1}{2}$  inches. It weighed 25 lbs.

The largest example taken during the survey was 63 inches long, but no record was made of the width of the disk or other measurements.

A rather interesting condition of spinulation is exhibited by a young female, measuring  $22\frac{1}{2}$  inches across the disk, which, though derived from the North Sea, is useful for comparison with the Irish specimens, since no others from Irish waters are available. The median caudal row is fairly complete, eight spines remaining, while scars mark the sites of two others. The spines, however, are much worn, nothing but the base and a slight apical prominence remaining. The lateral rows are only represented by one spine on one side, and two on the other, all posterior to the commencement of the first dorsal fin. They are evidently of recent growth, since they are quite perfect and sharp, and, no doubt, represent the first appearance of the more or less continuous row, which manifests itself in

larger examples.\* Thus it would appear that the long-nosed skate resembles its common ally in the spinulation formula, since in *R. batis* only a central row is present in very young examples. The absence of median spines is a frequent feature in old common skates, but we are not aware that any observer has considered it of specific value, when dealing with that form. The apparent anomaly that in such small species (*e.g.* *R. maculata*) as typically exhibit a tri-linear arrangement of the caudal spines, it is the lateral and not the median spines that are most often missing in old examples, is explained by the difference in the history of the individual spines. In the small species the lateral spines, which may, or may not, be present in the adult, are older than, or as old as, the median spines, since they replace smaller spines, occupying the same position in very young examples, at a period of the life history which presumably corresponds to that which we have been dealing with in the case of the young long-nosed skate. At about the same period the median spines of the Homelyn begin to be replaced by the intercalation of a new series; but in the large skates no such new series is developed, and whatever median spines may be present in old examples are only the remnants of the original series. It is easy to understand that the renewal of the dermal armature of the young is a feature that would naturally be lost in the evolution of a species which attains such a size as either *R. batis*, or *R. oxyrinchus*, the adults of which can have few enemies against which a prickly tail would be an efficient defence.

We have examined a mature male from Ireland; but can say nothing as to the spinulation of the tail, as that organ had, as usual, been cut off by the fishermen for convenience of packing, before the specimen reached our hands.

The dimensions are as follows:—

	Inches.
Width of the disk, . . . . .	35
Length of the snout, . . . . .	11½
Length of the eye, . . . . .	1½
Combined length of eye and spiracle, . . . . .	2⅜
Distance between the supra-orbital ridges, . . . . .	2½
Distance from tip of snout to centre of mouth, . . . . .	12
Distance from tip of snout to coracoid, . . . . .	19
Distance from tip of snout to anus, . . . . .	29½
Distance between the inner margins of nostrils, . . . . .	4⅛
Distance between the inner margins of either nostril and tip of snout, . . . . .	10¼
Length of the disk, . . . . .	30½

The claspers are fully elongated; the *vasa deferentia* swollen; but the testes and the alimentary viscera are wanting.

\* It will be remembered that the most posterior of the lateral spines were wanting in the largest examples, probably because these spines are the first to develop, and consequently the first to decay.

The upper surface of the disk is smooth, or very nearly so, over the cheek muscles, the gill-chambers, and the fleshy parts of the pectoral fins, as outlined laterally from the posterior alar sexual species forwards to the anterior alar patch, and backwards to the insertion of the pelvis. The lateral parts of the abdomen and the pelvic fins are also smooth. Elsewhere the upper surface is beset with asperities, minute over the vertebral abdominal region, and largest and most closely set on the anterior-third of the snout, and along the anterior margins of the pectorals. No large spines are present, exclusive of the sexual alar spines.

The under surface is everywhere beset with asperities, except on the claspers. The rest of the pelvic, and the posterior flange of the pectoral, is nearly smooth, while the asperities are most numerous, and largest, along the anterior margin.

There is thus between adult males and females only that difference in the development of the asperities of the disk which is characteristic of the genus.

The colour of the upper surface is a cold sepia, lightest on the head, except at the end of the snout. There are about 20 rather ill-defined roundish spots on the fleshy part of each wing. Each spot has a small pale yellow centre, from which the colour shades through yellowish-white into that of the general surface of the disk, the whole area of each spot being about three-eighth inch in diameter. The juncture of the anterior limb of the pectoral to the head is outlined, from opposite the eye forwards, by a row of black punctures. Similar punctures extend along the anterior margin, and are present in a small group near the posterior extremity of the pectoral. There are no dark pigment patches whatever; the under surface is an uniform grey, with black punctures.

A number of specimens of both sex, from Rockall, agree with the Iceland examples in the general arrangement of the pigment, but the prevailing colour is grey rather than brown, while the spots are whitish. The water on the "flat of the rock," where these specimens were probably caught, is from 30 to 40 fathoms deep, but it is quite possible that some may have come from much deeper water.

*Teeth.*—Day remarks that there are about 46 rows in the upper jaw, but does not say to what size of specimen this statement may apply. The specimen he figured was about 28 inches across the disk, if the scale of the drawing is correctly stated. The smallest example we have described has 38 rows, the larger teeth measuring about 1.4 mm. across the base. There is a short pointed central cusp, very feebly keeled in front, and a well-defined shoulder on each side. The 50 inch example from deep water has 48 rows in the upper jaw.

The Iceland male specimen has only 38 rows in the upper jaw, which is rather remarkable in view of the large size of the specimen. In the central part of the jaws the cusps are elongated, sharply pointed, and strongly keeled in front, and the shoulder fairly well-marked. These characters are less conspicuous in the lateral teeth.

*Colours.*—The grey of the undersurface was well marked in all living examples which we have seen, and is not, as is frequently the case in *R. batis*, the effect of *post-mortem* changes.

*Breeding.*—We have never recognised the egg-purse of this species, nor does it appear to have been described by other observers.

*Kidneys.*—We have examined these organs in two females, measuring respectively 36 and 22½ inches across the disk. In both examples they are asymmetrical, especially in the posterior region. The subjoined figure shows the condition in the larger fish, and in the smaller one the conformation is very similar, though not exactly the same. Attention has been drawn by Professor Howes ("Jour. Anat. and Phys." xiv., p. 341) to the frequency of asymmetry in the kidneys of *R. clavata*. The author figures several examples (Pl. xvii.), which in no case very closely resemble those before us, and suggests that the variation may represent the inception of a "condition to be sooner or later seized upon, and handed down to future generations of thornbacks as an inheritance of the past" (*op. cit.*, p. 421). From the examination of only two specimens it is impossible for us to say whether the character has become fixed in *R. oxyrhynchus*, or whether we have merely happened to remark two abnormal examples.



Kidneys of *R. oxyrhynchus*. Half natural size.

***Raia fullonica*, Linnæus. The Shagreen Ray. (Deep-sea).**

- Raia fullonica*, . . . . COLLETT, "Norges Fiske," p. 217.  
 ,, ,, . . . . GÜNTHER, "Proc. R. S. E.," xv., p. 206.

A specimen measuring 44 inches in length was taken at 154 fathoms, off Achill Head, on the 20th April, 1891. Others occurred at various depths between 32 and 80 fathoms, while one was caught in Killybegs outer harbour at 14 to 16 fathoms.

The species is known to occur at depths ranging from 80 to 250 fathoms on the coast of Norway (Collett), and Günther has recorded an example from 100 fathoms in Loch Fyne.

It occurs commonly on the Farœ "banks," and off the coast of Iceland, but we are not certain that it has been taken below the 100-fathom line in these localities. The southern limit of its known horizontal range is Madeira. In the British Islands it appears to be more plentiful on the coast of Devonshire than elsewhere; it is certainly not abundant on the east coast, but Couch\* has recorded examples from 50 fathoms in the Moray Firth, while a single specimen has been met with by one of us in the shallow water of Findhorn Bay in that locality. On the whole the Shagreen Ray would appear like *R. oxyrhynchus*, to affect rather deep water around the British coast.

***Raia microcellata* (Montague). The Owl Ray. (Littoral).**

<i>Raia microcellata</i> ,	. . .	MONTAGU, "Wern. Mem.," ii., p. 430.
" "	. . .	FLEMING, p. 171.
" "	. . .	JENYNS, "Manual," p. 515.
" "	. . .	MÜLLER & HENLE, p. 142.
" "	. . .	YARRELL, "Brit. Fishes" (ed. 3), ii., p. 567.
" "	. . .	DAY, "Fish. Great Brit.," ii., p. 346.
" "	. . .	MOREAU, "Poiss. de la France," i., p. 417.
" "	. . .	HOLT, "Report. Roy. Dub. Soc.," 1892, p. 305.
<i>Painted Ray</i> ,	. . . . .	COUCH, "Fish. Brit. Isles," i., p. 107.

DIAGNOSIS OF SPECIES.—Anterior edge of the disk slightly undulating, scarcely passing in front of a straight line drawn from tip of snout to angle of pectoral fin. Extremity of snout projecting slightly. Width of the disk about 26 per cent. greater than its length, and about 30 per cent. less than the total length, which is about 7 times the length of the snout. Length of the eye about  $5\frac{1}{2}$  times in the length of the snout, and from 2 to  $3\frac{1}{2}$  times in the distance between the interorbital ridges. Spinacles of greater diameter than, and placed close to, the eyes.

*Teeth* of adult males pointed, of females obtuse. Both upper and under-surfaces of disk and tail covered with asperities. A median dorso-caudal row of spines in both sexes. Two lateral caudal rows in females; adult males with a single lateral row, always very imperfect, frequently altogether absent either on one or both sides. *Colours*—upper surface brown, inclining to madder or lilac, with a number of pale purplish streaks and spots arranged, on the wings, in a manner roughly parallel to the anterior and posterior margins of the disk: a few pale blotches over the abdomen, frequently accompanied by darker markings.†

\* "British Fishes," i., p. 118. † All markings are lost in specimens preserved in alcohol, or by drying.

Large examples may be uniformly coloured. Under surface white. The *linear spines* of the back differ from those of other species known to us in their comparatively small size, and greater abundance. The median row may be said to commence just opposite the posterior margin of the spiracles, as in this region there is noticeable an aggregation of very minute spines, hardly larger than the asperities of the general surface. These minute spines, passing backwards along the middle line, increase gradually in size, but cannot be said to become conspicuous as linear spines until the pectoral region is reached. Throughout the whole length of the median row the spines continue to be crowded together in somewhat the same manner as the spinules of the supra-orbital ridges in many species, and frequently, by overlapping each other, present a zigzag arrangement.

Although attention was specially directed to this species during the survey, as previously unfamiliar to us, we were never able to obtain specimens of less than 16 inches across the disk. All our material being therefore adult, or nearly so, it is impossible for us to speak of any changes of spinulation which may take place during the younger stages. From the very different character of the adult caudal spinulation in males and females, to which we have already alluded in our introductory remarks (p. 381), it is very evident that some changes do occur. A female, 12 inches across the disk, is depicted by Day (*op. cit.*, Pl. clxxii.) This specimen has no lateral caudal spines at all. It would therefore appear that the condition of spinulation exhibited by our specimens is characteristic of adults only, the lateral spines, as in the case of *R. batis*, being only developed late in life. Such a hypothesis may receive some further support from the embryo figured by Couch (*op. cit.*, p. 109), in which, as in very young *R. batis*, there is a single median row only. The larger specimen described by the same author had a single lateral row. It measured 24 inches across the disk, and appears to have been a female. Day remarks that the general surface is occasionally quite smooth, which may very probably be the case in young examples. He also says, on the authority of some person not specified, that old examples may have the upper surface of an uniform grey colour. All the survey examples, however, were marked in the manner indicated in the diagnosis.

Fourteen examples were taken during the survey, viz. one in Blacksod Bay, four in Loughrosmore Bay, and nine in Boylach Bay. The last two bays are contiguous. The depth of water varied from 5 to 19 fathoms. It seems, therefore, that the owl ray is extremely local on the Irish coast, as it is too conspicuous a species to have been overlooked if it had been captured elsewhere. It seems to be essentially an inshore fish, and, previous to the survey, was not known to inhabit Irish waters. It occurs also on the south coast of England, and on the coast of France.

Our largest example was a female measuring  $23\frac{3}{4}$  inches across the disk, and 34 inches in total length. We give a figure of an egg-case taken from this example. It measures 9.10 cm. long, by 5.7 cm. broad. Plate XLIV., fig. iv.

***Raia circularis* (Günther).** The Sandy Ray. (Deep-sea).

*Raia circularis*, . . . . . GÜNTHER, "Cat. Fish. Brit. Mus.," viii. p. 462.  
 ,, ,, . . . . . COUCH, "Charlesw. Mag. Nat. Hist.," 1838. ii.,  
 p. 71.

(Sandy Ray) *Raia circularis*, . COUCH, "Fish. Brit. Isles," i., p. 115.

(Cuckoo Ray) *Raia miraletus*, . COUCH, "Fish. Brit. Isles," i., p. 112.

Couch, in describing the sandy and cuckoo rays as distinct species, based his diagnosis on the well-known differences in the colouration. The sandy ray is uniformly chocolate-brown on the upper side, save for a very few small white spots on the wings, while the cuckoo ray is a pale yellowish-brown, with a very distinct large black and yellow ocellus on each wing.

Dr. Günther, failing to recognise any distinctions of specific value, associated the two forms under the name *R. circularis*, the specific name given to the sandy ray by Couch (*loc. cit.*), and his example has since been followed by all writers of note.\*

The material obtained during the Survey affords no reason for combating this arrangement, but it may be as well to state to which colour variety the different specimens belong.

The species is generally distributed along the west coast of Europe, and in the Mediterranean. It has been recorded by Collett,† from a maximum depth of 370 fathoms off the coast of Norway, and by Günther, from 516 fathoms in the Farøe channel, who has drawn attention to the peculiar colouration of the specimen obtained on that occasion.‡ The lower parts are described as "nearly uniform blackish-brown." Our own examples, from deep water, had the under-surface white, as usual. So far as we are aware, no examples answering to the description of the cuckoo ray have been taken in very deep water, whereas the sandy ray occurs in quite shallow water, as well as considerable depth.

We believe that the egg-case of *R. circularis* has never been figured, and therefore append a drawing. Plate XLIV., fig. iii.

\* Including Collett, "Norg. Fisk.," p. 214; Moreau, "Poiss. Franc.," i., p. 397; Day, "Fish. Gt. Brit.," ii., p. 348; and Lilljeborg, "Sverig. o. Norg. Fisk.," p. 564.

† "Mag. f. Naturvid.," xxix., p. 119.

‡ "Chall.," xxii., p. 8.

***Raia blanda* (nobis). The Blonde. (Littoral).**

- Raia blanda* (H. & C., *M.S.*), HOLT, "Journ. Marine Biol. Assoc.," vol. iii., No. 3, p. 181.
- Raia maculata* (part), . . . COUCH, "Brit. Fish.," p. 104.
- " " (part), . . . DAY, "Fish. Great Brit.," ii., p. 345, pl. clxxii.
- Raia asterias* (part), . . . MOREAU, "Poiss. Franc."
- Raia brachyura* (?), . . . LAFONT, "Soc. Linn. Bord.," xxviii., 1873, pl. 25.

DIAGNOSIS OF SPECIES.—Reaches a width of over 30 inches. Males become mature at a width of about 24 inches. The egg-purse has a length of about  $5\frac{1}{2}$  inches, exclusive of attachment processes. Anterior profile obtusely rounded, the extremity of the snout projecting as a short *semicircular* process, except in adult males, where it is more or less conical. Anterior margin of disk twice projecting in front of a line drawn from the tip of the snout to the angle of the pectoral fin, the convexities most marked in adult males; the outer margin would meet at about a right angle. Width of the disk about 25 per cent. greater than in its length, and about 30 per cent. less than the total length; the tail slightly the longer in the male. The distance between the nostrils equal to, or rather less than their distance from the snout. The length of the snout from  $4\frac{3}{4}$  (in young) to nearly  $5\frac{1}{2}$  times (in adults), and the distance between the tip of the snout and the anterior edge of the coracoid from  $2\frac{1}{2}$  (in young) to  $2\frac{6}{11}$  times (in adults) in the width of the disk. The length of the eye from  $1\frac{1}{2}$  times (in young) to twice (in adults), in the distance between the supra-orbital ridges, which is equal to, or (in large examples) greater than the combined length of the eye and spiracle. Teeth small, obtuse in females and in immature males; sharply pointed in adult males; arranged in from less than 60 to over 90 rows in the upper jaw, as follows:—

In specimens about 9 inches across the disk, about 66 rows.

"	"	"	16	"	"	"	74	"
"	"	"	23	"	"	"	78	"
"	"	"	29	"	"	"	93	"

The supra-orbital ridges have usually a few small spines at each end. Small spines along the rostral ridges, and a spine on each shoulder in young, and sometimes in half-grown, examples. A row of spines runs along the median dorsal line from behind the head. *In young examples three or four spines of this row are in front of the shoulder.* In half-grown and adult examples spines frequently are absent from in front of the shoulder; if present, very small. In males they are usually absent from in front of the pelvic region. A row of spines is situated on each

side of the tail in young examples; irregularly double in its anterior region in adult females, may be absent in half-grown examples of either sex; usually absent or incomplete in adult males.

Small asperities are confined to the prepectoral region of the disk in young examples. They *extend all over the upper surface*, in half-grown examples of either sex and in adult females. The anterior flange of the pelvic in females, and the whole of the pelvic in males, is smooth. The gill-region and central part of the pectoral is smooth in adult males. Asperities are nowhere very clearly set except on supra-orbital ridges and along anterior margin.

The under surface in examples of either sex, 9 inches or more across the disk, shows a *border of very close, backwardly directed asperities along the anterior margin*, not extending to the angles of the pectoral. Scattered asperities extend from the central part of this border over the interhuial region in adult males; less frequently in adult females. A narrow border of closely-set asperities along the edge of the tail in examples of 10 inches or more across the disk. Some asperities about the region of the coracoid and anterior part of the abdominal cavity in half-grown examples of either sex, and about the general surface of the tail in females. Adult females with scattered asperities over the general ventral surface, except the outer parts of the pectoral and pelvic fins.

*Colours.*—The upper surface a pale fawn, may incline to chestnut, rarely to cold sepia; usually darker on the abdominal region and lighter on the head than on the rest of the body. Thickly sprinkled with small dark spots, seldom exceeding quarter of an inch in diameter, *which extend to the margins of the disk*. A number of small pale, rounded areas, having a certain bilateral symmetry of arrangement, on the wings; rarely with a central dark "pupil" spot; surrounded by a ring of spots never much larger than the rest, and *never continuous with each other*. Transverse pale streaks, destitute of spots, may be present near the margins of the disk. Under surface white, occasionally brown on the projection of the snout.

The existence of two species of spotted rays in British waters was first suspected by one of us during the cruise of the "Harlequin," when it was noticed that the fish taken in Blacksod Bay and several other localities seemed to fall into two groups, one consisting of large, pale, small-spotted individuals, while the rest were smaller, darker, and usually with larger and less numerous spots. It was also noticed that the larger fish yielded an egg-purse twice the size of any that were obtained from the smaller. Differences in external characters were carefully noted, but a difficulty in separating the two kinds arose from the impossibility of obtaining small examples of the pale, small-spotted fish. Hence, though a strong opinion might be formed as to the specific distinction, it seemed impossible to prove to the satisfaction of readers that the condition exhibited by the larger fish

might not be arrived at through stages in which there were no possibility of distinguishing the two, and, therefore, that such difference as existed was of specific rather than varietal value. Accordingly, in drawing up the preliminary reports, no attempt was made to separate the pale from the dark fish (though some allusion was made to the matter),\* and, indeed, it would have been impossible to do so with even approximate correctness.

In discussing the matter with Dr. Günther, to whom we are indebted for much valuable advice and information in connection with this Paper, he expressed the opinion that there must be two species, and referred to a record by Dr. Day of the occurrence in British waters of a ray designated by him as *R. punctata* (Risso). Dr. Günther considered the identification incorrect, and the record is further confused by a want of agreement between the description and the specimen in Day's collection to which it appears to refer.†

The description makes the teeth "larger" than in the Homelyn, whereas they are in reality smaller, and in this, as in other respects, the specimen agrees with the large pale forms from the west of Ireland. Owing to the great size it was only possible to preserve the jaws of some of these examples, and even in this respect our material is less complete than might be wished. Fortunately, however, we have again met with the fish in the North Sea, and have obtained a series which puts its specific distinctness from the Homelyn beyond doubt.

The two species are sufficiently unlike each other, at equal sizes, to be distinguished at a glance, but the distinctive characters do not admit of very terse definition, and the diagnosis which we have drawn up is accordingly somewhat unweildy. Still, long as it is, we think there it need of a few further remarks.

The colouration, no doubt, is the feature which most readily arrests the eye in any species, and that of the Blonde (a vernacular designation) differs conspicuously from that of many Homelyns, in that the ground is paler and the spots smaller, more numerous, and more universally distributed than in the Homelyn. Among fish taken on the same ground, and quite fresh, the Blondes, and especially the large ones, are always paler than the Homelyns; but, in a casual market assortment, from various grounds and in various stages of freshness, this difference is not invariably apparent. The spots are never so large in the Blonde as they may be in the Homelyn, and are always close together; but we have seen a Homelyn that could not be distinguished from a Blonde by these markings alone. Moreover the spots came very close to the margin of the disk, the unspotted border being very much narrower than is usual in this species; still, they did not actually reach the posterior margin of the wing, as they always appear to do in Blondes. The

\* Holt, "Sci. Proc. Roy. Dub. Soc.," vol. vii., 1892, p. 427.

† The specimen was not labelled at the time it came into the possession of the British Museum. Its identity with the specimen described must therefore remain in doubt.

value of the alar ocelli as a specific character is difficult to express succinctly ; but it may be said that all Blondes have a number (about five or more) of small pale circular areas on each wing, which can readily be seen, and which, in fact, cannot escape observation, whereas in the Homelyn, if conspicuous ocelli exist at all, there is only one on each wing (in the position in which an ocellus is found in the young of every species of ray with which we are acquainted), and any other pale areas that may exist require a more careful search, and, when found, are seen to lack the definite rings of spots which invariably encircle their homologues in the Blonde.

The shortness of the rostral projection in the Blonde imparts to the anterior profile a shovel-like appearance which is wanting in the Homelyn. In the shape of the disk, in fact, the Blonde resembles *R. microcellata* more than the Homelyn, and the difference is especially noticeable when specimens of about the same size are compared. As we have noted in our introductory remarks the anterior margin of the wing becomes more sinuous with age, and Homelyns are always more advanced in adult characters than Blondes of corresponding size, since *R. maculata* is by far the smaller species. Of course the difference is most marked when a mature male Homelyn is compared with a male Blonde of the same size and consequently immature. An old male Homelyn has a snout somewhat resembling that of *R. fullonica*, though, of course, shorter, whereas in even the oldest male Blondes the tip of the rostrum is merely a broad cone ; its sides practically continuous with the anterior convexity of the front margin of the wing. The smallest Blonde we have seen measures a little less than nine inches across. Very small specimens probably resemble young Homelyns pretty closely, as far as the shape is concerned ; and indeed this character is much alike in the youngest stages of all the short-nosed rays.

The smaller size of the eye, and the difference in its relations to the width between the supra-orbital ridges is apparent enough where specimens of the same size are concerned. The other differences of proportion are most readily brought out by measurement, and do not appeal at once to the eye.

The formula of the linear spines is identical in the two species, but of course the difference in ultimate size involves a difference in the development of the spines when examples of the same size are compared. Thus, the large spines which replace the original lateral caudal row of the young ray, may have made their appearance in a Homelyn only 12 inches across, and may be, or, perhaps, always are still absent in a Blonde with a transverse measurement of 18 inches. Further, if specimens of about 9 inches be compared, the spines will be found the smaller in the Blonde, and their bases seem always to have a yellowish tinge, not observable in those of the Homelyn. The presence of more than two spines in the middle line in front of the shoulder in young Blondes seems to be a character of

constant specific value. It is only in old Homelyns that more than two may occur in this region, and they seem to be always very small, in fact not much larger than the surrounding spinules. They belong to the secondary series, and may occur also in old or half-grown Blondes. In Homelyns exceeding 12 inches in transverse measurement it is unusual to find shoulder spines; in the Blonde these structures would seem to disappear, as a rule, when the disk is at a width of about 14 inches; but we have seen a specimen, 38 inches long, and therefore, probably, about 26 inches wide, in which they were still retained. The smaller spines and larger spinules have distinctly radiate bases in young examples of either species.

In the Blonde the upper surface becomes practically covered with spinules when the disk is a width of 16 inches, the smooth condition of certain areas in the adult male being only attained, or rather re-attained, at a size which the Homelyn never reaches. The spinules are never very clearly set, except in certain regions mentioned in the diagnosis, and thus differ from those covering the general surface in *R. clavata*, *R. microcellata*, and some other species.

On the under surface, *the border of very closely-set spinules along the anterior margin*, is an infallible character, since such is never present in the Homelyn at all.\* In Blondes of a little under 9 inches it is perfectly distinct, though narrow; it extends laterally to the level of the gills. In specimens of about 18 inches it is about  $\frac{5}{16}$  inch wide, except at the lateral extremes, which are narrower, and terminate at points where a straight line drawn through the nostrils would cut the anterior margin. In full-grown Blondes the extremities of the border are approximately on a level with the corners of the mouth. The narrow border of closely set spinules along the edges of the caudal undersurface is another useful character. It is present in all Blondes of 10 inches, and upwards, and entirely absent from any stage of the Homelyn.

In specimens of equal size, *the teeth are always smaller and more numerous* in the Blonde than in the Homelyn; but in both species they seem to vary a good deal both in number and size, apart from the regular developmental changes in these characters. There remains, however, a distinction quite sufficient for systematic purposes, so long as the size of the individual is considered. Thus, a Blonde 9 inches wide has 66 rows; a Homelyn  $9\frac{1}{2}$  inches wide, only 49 rows; Blondes  $10\frac{1}{2}$  and 11 inches wide have 62 and 66 rows; Homelyns of  $11\frac{1}{8}$  and  $11\frac{3}{4}$  inches, 51 and 45 rows; a Blonde  $16\frac{1}{4}$  inches, 74 rows; a Homelyn,  $16\frac{3}{4}$  inches, 51 rows; and another,  $17\frac{3}{8}$  inches, only 50 rows. A Blonde,  $21\frac{1}{2}$  inches, 74 rows; a Homelyn,  $19\frac{1}{2}$  inches, the largest we could procure, 66 rows. The difference here is not great, but we imagine, from comparison with larger and smaller specimens, that the Blonde in question exhibits about the maximum

\* It occurs, however, in *R. asterias* (Müll. and Henle), and in *R. punctata* (Risso), and in other spotted rays from the Mediterranean.

degree of reduction in the number of its teeth. Taking specimens of equal size, the largest teeth in the upper jaw seem usually to be nearly one-third larger in the Homelyn than in the Blonde.

The egg-case of the Blonde is easily distinguished from that of the Homelyn by its greater size. Exclusive of the attachment processes, a purse of the Blonde, the parent being 46 inches long, measures 13·6 cm. in length, whereas one taken from a Homelyn, 28 inches long, measures only 6·7 cm. The width of the Blonde's purse is 7·6 cm., the Homelyn's being 4·8 cm. wide. Thus the purse of the Blonde is narrower in proportion to its length, and is moreover more rectangular in shape, the ends especially being almost parallel. There is not much difference in the relative length of the attachment processes in the two species, and the external surface is equally smooth in both. Both egg-cases are figured. Plate XLIV., figs. i. and ii. (Blonde and Homelyn respectively).

DISTRIBUTION.—Blondes were more abundant in Blacksod Bay than elsewhere along the coast, but were taken also in Ballinskelligs Bay, off the Aran Islands, in Clew Bay, and off Downpatrick Head. As we have already remarked, no small specimens were observed anywhere during the Survey, though many were sexually immature. None were taken in more than 29 fathoms, whereas they were frequent in less than 10 fathoms. Homelyns were almost invariably taken wherever Blondes occurred, and it would seem that the two species have much the same *habitat*, though the Homelyn is the commoner of the two, and, as far as our knowledge goes, extends into deeper water off the west coast of Ireland. In the North Sea large Blondes are moderately abundant, and small ones are occasionally taken on certain grounds lying about 20 to 30 miles east of the Spurn, the depth being less than 20 fathoms. Homelyns occur more abundantly on the same grounds. Owing to the confusion of the two species in works on British Ichthyology, it is not easy to learn much of the distribution of the Blonde from such sources, but the fish figured by Day as a Homelyn is certainly a Blonde, and is stated to have come from Plymouth. The specimen of which Couch gives the measurements must also have been a Blonde, so that the species evidently occurs on the Cornish Coast. *R. asterias* of Moreau, which we interpret as comprising both the Blonde and Homelyn, is described as common on all the coasts of France, and also to be found in the Mediterranean. Making allowance for the possibility of only one form, the Homelyn, being possessed of such a wide range, it is still probable that the Blonde extends a considerable distance south of the British Isles. Should it prove to be identical with *R. brachyura*, Lafant, its occurrence will be definitely established on the coast of France.

Names.—The name "Blonde" is that applied by Grimsby fishermen and fish-merchants to *R. blanda*. In advance of ichthyologists, they have long recognized the fish as distinct from the "Homelyn," *R. maculata*. The Blonde, chiefly

on account of its greater size, is of much higher value than the Homelyn, and is also more valuable than the Thornback, though the latter is often quite as large. It is, in fact, one of the most valuable species of *Raia* which finds its way into the Grimsby market. Young Blondes, on account, as we suppose, of their comparative rarity and low value, are not universally recognised as distinct from adult Homelyns, but there are fishermen and merchants who can distinguish the two forms at all stages. The name is said to have been derived from the Belgian fishermen, but whether this is really the case we have no means of determining. In our choice of a specific name we were actuated by the desire of approaching the vernacular name as closely as possible, while adhering to the ordinary rules of scientific nomenclature. Blanda is an epithet descriptive of mental rather than physical condition, and we cannot claim that in this sense it is actually appropriate. Still, considering the host of closely allied species, the name is probably as distinctive as any that could have been coined from the physical characters of the species.

REMARKS ON THE SYNONYMY.—As is apparent from the synonymy which we have given above, we consider that Blondes and Homelyns have been pretty generally confused by authors who were acquainted with examples of both species.

It is possible that even Montague failed to distinguish between them, since he states that his species *R. maculata* grows to a larger size than *R. clavata*, whereas the Thornback is larger than the Homelyn in any district of which we have experience. If the author regarded the Blonde as merely a large Homelyn, his statement would be perfectly intelligible, but his specific description is evidently taken from the Homelyn, and not from the larger species. Hence we have no hesitation in retaining the name of *R. maculata* for the Homelyn, since the correctness of the diagnosis is not impaired by any confusion which may possibly have existed in the mind of the author.

Couch's description is too inexact to enable us to be certain whether it is intended to apply to one species or to both. The specimen selected for special description would appear from its size, and from the roughness of the upper surface, to have been a Blonde, but the colouration of the figure is apparently taken from a Homelyn, and no doubt the author's general remarks are chiefly meant to apply to examples of that species. Day's diagnosis of *R. maculata* refers chiefly to the Homelyn, but from his remarks on the dentition it is evident that he confused that species with the Blonde. Moreover, his figure which, as appears from the text, was taken from an immature male 25 inches across the disk, must certainly have been taken from a Blonde. The author remarks that the spots in this specimen were rather closer together than usual; but it is probable that the drawing does not very accurately represent the original either in markings or some other details.

The *R. asterias* of Moreau appears, so far as that author's somewhat loose mode of expression permits us to judge, to comprise both the Blonde and the Homelyn. It is certainly not the *R. asterias* of Müller and Henle. His description of the border of spines along the anterior margin of the under surface of the disk appears to indicate one of the most pronounced features of the Blonde; but in his description of the dorsal surface, as being almost smooth with slight spinules on the anterior margin of the pectorals, and around the scapular arch, he certainly must have had the appearance frequently found in the Homelyn present to his mind.

Under the name of *R. brachyura*, Lafont\* described and figured a spotted ray, which was certainly not a Homelyn, and may possibly have been a Blonde. The description, however, is quite inadequate, while the figure is primitive in the extreme. The formula of the linear species agree with that of either *R. blanda* or *R. maculata*. Six are shown in the median series extending from behind the level of the spiracles to the abdominal region, the series reappearing posteriorly on the tail.

The snout is short, the disk, according to the drawing, rhomboidal, with six large white spots on each wing. Smaller dark spots are universally distributed over the disk, except on the head, but are not shown as surrounding the pale areas. It is noted that the latter have been made rather too conspicuous by the artist. The tail is stated to be broad and flat, and much shorter than the disk, though this last character (as compared with other species) is not brought out by the measurements given. There are said to be eighty-five rows of teeth in the jaws, but the size of the individual from which this observation was taken is not mentioned. The teeth resemble those of the side rows of a young *R. batis*. Certain measurements are given of two specimens, from which it appears that the proportions of the length and breadth of the disk and the length of the tail do not conspicuously differ from those of either the Blonde or the Homelyn. It further appears that the diameter (longitudinal or transverse?) of the eye is contained five and a-half times in the width of the inter-orbital space. The individuals measured are, an immature male 88 cm. long, and as female 113 cm. long.

It is expressly stated that neither spines nor "aiguillons" exist on the under surface, but it is not certain whether these terms can be interpreted to include asperities or minute spinules such as form so well-marked a feature on the under surface of the Blonde. The omission of all reference to such asperities renders it quite impossible to identify *R. brachyura* with *R. blanda*, while the general inadequacy of the description renders it equally impossible to say what species Lafont had before him. It may possibly have been *R. asterias* (Müller and Henle). The specimens were obtained from the Gironde and from Arcachon, where the species is known to fishermen as the *Raia blanche* or *lissee*.

\* "Soc. Linn. Bordeaux," xxviii., 1873, p. 503, pl. 25.

***Raia maculata*, Montagu. The Homelyn. (Littoral.)**

- Raia maculata*, . . . . . MONTAGU, "Wern. Mem.," ii., p. 426.  
 " " . . . . . PARNELL, "Wern. Mem.," vii., p. 434.  
 " " . . . . . GUNTHER, "Cat. Fish. Brit. Mus.," viii., p. 458.  
 " " (part), . . . . . DAY, "Fish. Grt. Brit.," ii., p. 345 (nee. fig.).  
*Raia rubus*, . . . . . DONOVAN, "Brit. Fish.," i., pl. xx.  
*Raia miraletus*, . . . . . DONOVAN, "Brit. Fish.," iv., pl. ciii.  
 " " . . . . . JENYNS, "Manual," p. 518.  
 " " . . . . . YARRELL, "Brit. Fish." (3rd ed.), ii., p. 570.  
*Raia asterias* (part), . . . . . MOREAU, "Poiss. de la Franc.," i. p. 429.  
 Spotted Ray (part), . . . . . COUCH, "Brit. Fish.," i., p. 104.

The following diagnosis is added for the purpose of further emphasising the characters which separate this from the preceding species:—*R. maculata* reaches a width of about twenty inches across the disk. Males become mature at a width of about fifteen inches (or less?). The egg-case about two and a-half inches long, exclusive of attachment processes, is seen in Plate XLIV., fig. ii.

The extremity of the snout slightly projecting; rounded in young, conical in half-grown and adult examples; rather sharply-pointed in old males. Anterior margin of disk twice projecting in front of a straight line drawn from the tip of the snout to the angle of the pectoral fin; the convexities most apparent in adults, especially males.

The distance between the supra-orbital ridges equal to the length of the eye in young; one-third greater than that measurement in adults; never greater than the combined length of the eye and spiracle.

The length of the snout from  $5\frac{1}{3}$  to  $5\frac{1}{2}$  times, and the distance between the tip of the snout and the anterior edge of the coracoid from  $2\frac{2}{3}$  in young to  $2\frac{3}{5}$  times, in adults, in the width of the disk.

The supra-orbital ridges usually with two spines at each end. A row of spines along the median line from behind the head, the last spine usually between the dorsal fins. *In young examples only two species of this row are in front of the level of the shoulder.* In half-grown and adult examples spines usually absent from in front of the shoulder; if present, very small; in males usually absent from in front of the pelvic region. A row of spines on each side of the tail in young examples; may be absent in half-grown examples; usually incomplete or absent in adult males; irregularly double in its anterior third in large females. Small spines along the rostral ridges, and a spine on each shoulder in young examples.

Small asperities confined to the pre-pectoral region of the disk in young examples. Present on the inter-orbital space, rostrum, distal part of anterior half of pectoral fins and tail in adults of both sexes. In *adult females* the whole of the upper surface rough, except the gill region, central part and posterior margin of pectoral fins, and pelvic fins.

The under surface perfectly smooth in young examples, and in adult males, except a few spinules on the snout and along anterior margin. In adult females a few asperities may be present on the coracoid, about the gill openings, and along the anterior border of the abdominal cavity. The under surface of the tail also with scattered asperities.

*There is never a ventral border of closely-set asperities along the anterior margins, nor along the edges of the tail.*

Teeth obtuse in females and immature males; sharply-pointed in adult males, of moderate size, arranged in about 20 to 70 rows in the upper jaw.

In specimens of about	4	inches across the disk about	23	rows.
„ „ „	9–14	„ „ „	45–50	„
„ „ „	19	„ „ „	66	„

*Colours.*—The upper surface usually a yellowish brown or cold sepia, rarely a greyish chocolate or dark grey. Dark brown spots more or less plentifully distributed, always absent from the posterior margin of the wing, and usually from its immediate neighbourhood. In rare cases altogether absent. In half-grown and young adult examples frequently a distinct and rather large pale ocellus on the wing, with or without a dark “pupil” spot, and *surrounded by a ring of spots, and more or less continuous with each other.* Smaller and less distinct pale areas, not surrounded by definite rings of spots, may be present elsewhere on the wings. Under-surface white.

*DISTRIBUTION.*—The Homelyn was found during the Survey all along the west coast. The greatest depth recorded is 48 fathoms, in the Kenmare River, but the majority were taken in less than 30 fathoms. It appears to be generally distributed on all the coasts of Great Britain, and occurs also on the coast of France. It has not been found in Scandinavian waters. Moreau describes his *R. asterias* as not only common on all the coasts of France, but as sufficiently common in the Mediterranean.

## TELEOSTEI.

## Family PERCIDÆ.

Genus *Pomatomus*, Risso (*nee* Lecép).

"Eye very large, seven branchiostegals. All the teeth villiform, without canines, no teeth on the palatine bones. Two dorsals, separated by an interspace, the first with seven, the anal fin with two spines. No denticulations on the edges of the bones of the skull, operculum, with two very feeble points, preoperculum with prominent rounded and striated angle. Scales moderate, slightly adherent. *Pancreatic caeca* in considerable numbers." (Günther.)

*Pomatomus telescopium*, Risso. (Deep-sea).(Pl. XLII., figs. 3, 3*a*, 3*b*, 3*c*.)

- Pomatomus telescopium*, . . . RISSO, "Ichth. Nice.," 1810, p. 301.  
 " " . . . CUV. ET VAL., "Hist. Nat. Poissons," vol. ii.,  
 p. 171, and vol. vi., p. 495.  
 " " . . . VALENCIENNES, "Hist. Nat. Iles. Canar. Poiss.,"  
 p. 6.  
 " " . . . LOWE, "Proc. Zool. Soc. Lond.," 1843, p. 91.  
 " " . . . GÜNTHER, "Cat. Fish. Brit. Mus.," vol. i., p. 250.  
 " " . . . MOREAU, "Poiss. de Franc.," vol. ii., p. 386.  
*Pomatomus telescopus*, . . . VAILLANT, "Exp. Sci. 'Travailleur' et 'Talis-  
 man,' Poiss.," 1888, p. 376.  
*Pomatomus telescopium*, . . . HOLT, "Proc. Roy. Dub. Soc.," vol. vii., p. 121.

Br. vii.; D. i. 7; D. ii. 1/10–11; P. 18; A. 11–12; L. lat. 40–53.\*

DIAGNOSIS OF SPECIES.—Length of head about  $2\frac{3}{4}$  times in length of fish without caudal fin; greater than extreme height of body. Diameter of eye more than  $\frac{1}{3}$  length of head, slightly greater than length of snout. Interorbital space wide. A well-marked transverse depression in front of interorbital space. Lower jaw the longer. Maxilla extends to about level of centre of eye. Upper jaw protrusible. Membrane of mouth ample. Anal papilla rather protuberant, slightly anterior to median point. All fins rather small. Scales large, very

\* Günther, Cat. makes L. lat. 40. We count 53 in our specimens.

thin, ctenoid, deciduous. Small scales present on the head and fins (except first dorsal). Colouration variable, prevailing tone pale slate-grey; somewhat darker on fins, and on gill cover, which exhibit a purplish sheen. Darker examples become brown or moroon grey. Branchiostegal, and mouth membranes deep black. Eye green. In alcohol, pale specimens assume a purplish hue.

DISTRIBUTION.—Risso, in his original description does not state the depths from which he obtained his specimens, merely remarking that it inhabits “les grande profondeurs.” Max Webber and Berthelot obtained the specimens studied by Valenciennes from depths of 250 fathoms. The examples procured during the cruises of the “Travailleur,” and the “Talisman,” described by Vaillant, came from depths varying from 222 to 527 fathoms.

As the species seems never to have been recorded from less depths, we may conclude that it is confined exclusively to deep water.

Two specimens, measuring respectively 20·3 cm. (8 inches), and 12·7 cm. (5 inches), were taken by trawl net, on the 4th July, 1890, in 144 fathoms, 20 miles off Achill Head, county Mayo.

This is the first appearance of the species in British waters, and since it has never been taken by any dredging expedition in higher latitudes, this record of its capture may probably mark the northern limit of its range.

The researches of Risso, Valenciennes, Lowe, and Vaillant show that the species has its habitat along the Atlantic slope of the old Hemisphere from the Bay of Biscay to the Island of St. Helena, and occurs also in the Mediterranean, off Nice, and in the Straits of Messina. It is known to attain to a length of 2 feet, and is said to spawn off St. Helena in November. (Valenciennes.)

Anatomy.—A careful description of the visceral anatomy is given by Cuvier and Valenciennes, and agrees for the most part with the condition exhibited by our specimens. These authors, however, remark that the gall-bladder is large and hidden by the right lobe of the liver. In the specimens before us the gall-bladder, so far from being hidden by either lobe of the liver, extends well beyond the posterior extremity of the stomach, and in fact as far back as the commencement of the rectum. It is roughly tetragonal in section in the region of its greatest expansion, but nowhere attains any great width. Günther (“Challenger,” vol. xxii. p. 14, fig. 1), has noted an even greater development of the gall-bladder in another deep-sea perch, *Scombrops chilodopteroides*, Blkr., in which that organ actually reaches the posterior extremity of the visceral cavity. He also notes, as a feature of interest, that the intestine only makes one complete convolution. This is also true of *Pomatomus*, but the intestine is somewhat longer than in *Scombrops*, a result chiefly attained by a short secondary infolding of the curved region of the duodenum. The stomach is large and simple, the pyloric coeca, twenty-two in number, of moderate length; the rectum inflated; the anal papilla protruberant,

a condition not usually met with in percoid fishes. The air-bladder is large, forming the dorsal wall of the whole of the visceral cavity. The urocyt is spherical and rather thick-walled. Both specimens are immature males, the testes appearing as narrow bands attached to the ventral wall of the air-bladder on either side. We have not been able to detect the spleen, if that organ exists. A considerable amount of fatty matter adheres, in the large specimens, to the hæmorrhoidal vein.

A small vein, which occupies the usual position of the lienic, appears to receive part of the blood from the *rete mirabile*, but the greater part of the blood from that structure is received by a larger and more anterior vein, which, after uniting with the left spermatic, enters the Cuvierian sinus. At the point of juncture of the two veins last mentioned, there is in one larger specimen, an anastomosis between the two venous systems, by means of a branch which leaves the portal vein just before the latter splits up to enter the liver. The arterial system of the visceral cavity presents no points of interest.

DESCRIPTION OF SPECIMENS.—*Scales*.—The rather large, deciduous scales are typically ctenoid, but very thin and semi-transparent. In a scale from the neighbourhood of the lateral line about the central region of the body the whole of the exposed surface is beset by fine spines, arranged in about seven rows from before backwards (Pl. XLII. fig. 3 *a*). The spines of the third and sixth rows are the longest, whilst those at the extreme posterior edge are the stoutest. Each spine is attached to the body of the scale for the greater part of its length, having only a short free portion posteriorly resembling an arrow-head in shape (fig. 3 *b*). The spines of the lateral line scales (fig. 3 *c*) are few and feeble. Both examples were almost entirely denuded of scales by the time they came on board,\* but from those which remained, and from the distinctness of the scale insertions, we believe that we have been able in fig. 3 to reproduce the natural condition with tolerable accuracy so far as concerns the body itself. The lateral line scales were mostly *in situ*, but are perhaps shown in the figure with too great distinctness. Whilst all the other fins were evidently covered with small scales in their basal regions, the first dorsal seems to have been scaleless. It is difficult to judge to what extent the head is clothed with scales in the natural condition, and it is possible that the keel of the pre-operculum, conspicuous in the specimens in their present state, may be really marked in life by a continuous scaly integument.

*Lateral line*.—We find fifty-three scales in our specimens. The number given by Günther in the Catalogue is forty, so that considerable variation would appear to exist in this respect.

\* A result probably attributable to the presence of an enormous number of *Spatangus Raschii* in the net.

*Colour*.—Both specimens evidently belong to the pale variety mentioned by Lowe. In the fresh condition, the body was of an uniform pale slate-grey, the head similar, except on the gill cover, which was rather darker, with purplish “reflêts,” and might well be described by Valenciennes’ expression “gorge du pigeon.” The membranous folds of the jaw apparatus and the branchiostegal membranes were black; the fins dark grey. The action of alcohol has changed the general colour to a dark purplish grey.

In the fresh condition the eye appeared like a hemisphere of bright green glass, a condition common to the eyes of many abyssal species. No trace of internal structure, such as has inadvertently been shown in the drawing, was visible at the time of capture.

### Genus *Polyprion*, Cuvier.

*Polyprion cernium*, Valenciennes. The Wreck-fish. (Deep-sea.)

*Polyprion cernium*, . . . . . LOWE, “Fish Maderia,” p. 183.

„ „ . . . . . DAY, “Fish. Gt. Brit.,” i., p. 17.

No examples were met with during the Survey. The fish has a very wide range, and has occurred off the south-west coast of Ireland, and more frequently off the south coast of England. Such specimens appear to have been usually, if not always, found in the neighbourhood of floating wreckage, and were all of comparatively small size. This is intelligible from Lowe’s observation that the young live near the surface, while the largest are taken (at Madeira) at depths of 300 to 400 fathoms.

### Genus *Scorpæna*, Günther.\*

Head large, slightly compressed, usually with a naked groove in the occiput, armed with spines, and generally with skinny flaps; body covered with scales of moderate or rather large size, generally with skinny appendages. One dorsal, more or less deeply notched. Pelvics, thoracic; pectorals large, rounded, inferior rays frequently thickened; no pectoral appendage. Villiform teeth in the jaws, on the vomer, and generally on the palatine bones. Seven branchiostegals; not more than 25 vertebræ. No air-bladder. Pyloric coeca in moderate numbers.

\* We have endeavoured to remodel the generic diagnosis in accordance with Dr. Günther’s remarks in “Fisch. d. Südsee,” p. 74.

*Scorpena dactyloptera*, Delaroche. (Deep-sea.)

(Pl. XLII., fig. 1.)

- Scorpena dactyloptera*, . . . DELAROCHE, "Ann. Mus.," xiii., pl. 22, fig. 2.  
 " " . . . RISSO, "Ichth. Nice," p. 186; and "Faun. Eur. Mérid," iii., p. 369.  
 " " . . . GÜNTHER, "Ann. Mag. Nat. Hist.," 1889, p. 417.  
 " " . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 121 and 219.  
 " " . . . EAGLE CLARKE, "Naturalist," 1893, p. 81.  
 " " . . . HOLT, "Jour. M. B. Assoc.," 1893, 121.  
*Sebastes dactylopterus*, . . . GÜNTHER, "Cat. Fish. Brit. Mus.," ii., p. 99.  
 " " . . . VAILLANT, "Exp. Sci. 'Talis.' 'Trav.' Poiss.," p. 368.  
 " " . . . SCHARFF, "Proc. R. I. Acad.," 1891, p. 456.  
 " " . . . COLLETT, "Norg. Fish," p. 19.  
 " " . . . LILLJEBORG, "Sver. o. Norg. Fisk.," i., p. 107.  
*Sebastes imperialis*, . . . CUVIER & VALENCIENNES, iv., p. 336.  
 " " . . . LOWE, "Trans. Zool. Soc. L.," ii., p. 175.  
*Sebastes norvegicus*, . . . SCHARFF, "Cat. Fish. Mus. Dub.," 1889, p. 26.

DIAGNOSIS OF SPECIES (D. i. 11–12; D. ii. 1/12–13 A. 3/5).—The height of the body  $3\frac{1}{4}$ , the length of the head nearly  $3\frac{1}{4}$ , of the total length. The inter-orbital space deeply concave, with two naked bony ridges; its width about one-ninth of the length of the head. Jaws sub-equal, the upper extending behind a vertical line from the centre of the eye. Tongue distinctly free anteriorly. Five spines on the pre-operculum. Pectoral fin with the seven inferior rays thickened, and semi-separate in adults; three to seven pyloric appendages: twenty-four or twenty-five vertebræ.\* Colours red, banded with dark-red; or spotted or banded with dark-brown; abdomen pale; pharynx black.

The species has been repeatedly confused with *Sebastes norvegicus*, and for purposes of comparison we have given (Pl. XLII., figs. 1 and 2) an outline drawing of the head of *Sebastes norvegicus*, as well as a figure of the species now under consideration. The superior angle of the gill cover is rounded in *Scorpena dactyloptera*,

\* Mr. Sim, of Aberdeen, writing of this species under the name of *Sebastes norvegicus* ("Ann. Scot. Nat. Hist.," 1893, p. 47), gives the number of vertebræ as 25 to 26. One of the Survey specimens has 25, Günther's Catalogue gives the number as 24, and, in remodelling the genera of *Sebastes* and *Scorpena*, this author gives 24 vertebræ as the maximum in the latter. Since, however, *S. dactyloptera* is included in that genus, we have raised the maximum number to 25 (or 26?).

not carried to a point as in the "Norway haddock." The general outline of the head is also more rounded in *Scorpena*; and although the original figure of the species given by Delaroche shows the lower jaw projecting beyond the upper, as it does in *Sebastes*, this appears to be more the exception than the rule. Figures 1a and 2a show imaginary sections through the interorbital regions of the two species, and it will be noted that while in *Sebastes norvegicus* the space is broad and nearly flat, with hardly perceptible scale-covered ridges, in *Scorpena dactyloptera* it is comparatively narrow, deeply concave, and beset by a pair of conspicuous naked bony ridges. In *Scorpena dactyloptera*, also, the serration of the frontal over the superior margin of the eye is much more strongly marked than in *Sebastes norvegicus*. In this form the sub-orbital ridge is broad, obliquely directed, and covered with scales. In *Scorpena dactyloptera* it is narrow, roughly parallel to the long axis of the body, and entirely naked.\* In the last-named, the opening of the gill-cover is almost vertical, while in the "Norway haddock" it is markedly oblique. In addition, the scales in *S. dactyloptera* are considerably the larger.

A difference less conspicuous than any of the foregoing, but of much greater morphological importance, is found in the characters of the pectoral fin. In *Sebastes norvegicus* the rays of this fin are all alike, and united to the extremities; but in the species before us the seven lower rays are stouter than the rest, and in adults are separate for about half their length. The species thus recedes from *Sebastes* and the true *Perches*, and approaches the semi-ambulatory condition of the pectorals which characterises the *Triglidae*. A number of very young *S. dactyloptera*, measuring from 4 to 4.5 cm. long, taken off the Skelligs at 80 fathoms, have the pectoral fin entire; such is also the case in a specimen of  $4\frac{3}{4}$  in. (12 cm. ca) recorded by one of us from the Humber, but all larger examples which we have seen show a partial separation of the lower rays. Our artist has unfortunately treated this detached condition of the rays in the specimen figured as due to artificial causes, and has restored the membrane to the extremities.

With reference to the size at which the fish becomes sexually mature it is interesting to note that a specimen measuring  $7\frac{1}{2}$  inches was found to contain ova nearly ready for expulsion. The structure of the reproductive organs seemed to show that the species is oviparous (the "Norway haddock" is viviparous), and it is probable that the ova is pelagic, as in the case of certain Mediterranean species studied by Raffaele. The greatest size reached by the species appears to be about 24 inches, but those from the West of Ireland do not attain to that size. It is likely that the size at which maturity is reached varies somewhat in different localities.

When alive all the larger fish taken during the Survey, exhibited the following colouration:—The back was a brilliant vermilion, which colour descended in five

\* Our figure in this respect is in error, scales having been restored where none were actually present.

or six bands across the sides, shading gradually into the pink of the general surface. The under-surface white, or white with a tinge of yellow, shading into pink on the sides. The fins were pink, marked irregularly with vermilion. The iris was bright yellow.

In the very young examples previously alluded to, the transverse bars were dark-brown, and no red colour was present (*teste* Mr. Green) at the time of capture. Some fine adult examples captured off Troup Head, Aberdeenshire, now in the British Museum, show a certain amount of dark-brown in the transverse markings, and thus differ from all the larger Survey specimens. The very young examples have, without exception, a black spot covering the 6th, 7th, and 8th rays of the anterior part of the dorsal fin.

DISTRIBUTION.—*S. dactyloptera*, previously known as an inhabitant of the Scandinavian and Lusitanian areas, and of the southern Atlantic, has recently become established as a truly British species, without doubt breeding and permanently residing around the British shores. The first records of its appearance was given by Dr. Günther in 1889, from specimens taken by the "Flying Fox" at 250 fathoms off the south-west of Ireland. During the Survey, several adults and half-grown specimens were taken off the coasts of Mayo and Kerry at depths of 500, 220, and 154 fathoms, while a great number of young were obtained at 80 fathoms, off the Skelligs. Scharff, in examining several specimens taken by the "Lord Bandon" off the south-west of Ireland, was led to the discovery that a number of fish from the same locality, preserved in the Science and Art Museum, and labelled *Sebastes norvegicus*, belong really to the species now under consideration. It thus appears that *S. dactyloptera* has been captured off the coast as early as 1843, by William Andrews, while the species to which his specimens were referred is actually unknown in Irish waters.

On the English coast the first recorded example was washed ashore at Coatham Sands in Yorkshire in February, 1893 (Eagle Clarke). In April of the same year a specimen was received by one of us from the Humber Estuary, and the accounts of fishermen gave reason to suppose that others had been taken there about the same time. All these English examples were quite small. About the same time it transpired, as we are informed by Mr. Boulanger, that the species had been regularly taken off Troup Head, Aberdeenshire, where the soundings reach a depth of over 130 fathoms, but had previously been mistaken, as in Ireland, for *Sebastes norvegicus*. In Norwegian waters the recorded depth is from 100 to 300 fathoms, and off Madeira from 250 to 400 fathoms, but the species was taken during the expeditions of the "Travailleur" and "Talisman" at 54 to 527 fathoms. It has thus been found almost exclusively in deep, or at least in moderately deep, water, which renders the occurrence of a specimen in less than 5 fathoms in the Humber somewhat remarkable. The example found at Coatham

Sands may presumably have been carried by the tide some way after death, but there is no great depth of water for a very considerable distance in any direction. The Humber specimen was trawled in the ordinary way, and there was nothing to show that its surroundings were uncongenial. Professor Smitt is led by the incompleteness of his compilation ("Hist. Skand. Fish." Ed. iii., 1893, p. 154) to the observation that, north of Portugal, *S. dactyloptera* has never been found south of Norway.

Fam.—**BERYCIDÆ.**

Genus **Hoplostethus**, Cuv. et Val.

**Hoplostethus mediterraneum**, Cuv. et Val. (Deep-sea.)

*Hoplostethus mediterraneum*, . . GÜNTHER, "Ann. Mag. Nat. Hist.," 1889, p. 417.

This species was not met with during the survey, and is only known as British, from the capture of a single specimen by Mr. Green, in the "Flying Fox," off the S.W. of Ireland, at a depth of 250 fathoms. This, according to Dr. Günther, furnished the first exact record of the vertical habitat. Vaillant (*Exp. Sci.*, p. 378) has since announced its occurrence at depths of 75 to 777 fathoms off the coast of Morocco. Its horizontal range is very extensive, since specimens have occurred in the Mediterranean, at Maderia, off the Atlantic coast of the United States, and on the coast of Japan (*cf.* Günther, "Chall." xxii., p. 21).

It may be remarked that another member of the same family, *Beryx decadactylus*, Cuv. et Val., may not improbably occur in deep water within the British area, since examples have been taken off Bergen, in Norway. It is found also off the coast of Portugal, Madeira, the Azores and Canary Islands, and in the sea of Japan.

Fam.—**TRICHIURIDÆ.**

Genus **Lepidopus**, Gouan.

**Lepidopus caudatus**, Euphrasen. The Scabbard Fish. (Deep-sea.)

*Lepidopus argyreus*, . . . . . BALL, "Dublin. Nat. Hist. Rev.," ii., p. 45.

This species, of which a specimen has been recorded by Ball, from Dublin Bay, is included by Dr. Günther in the Challenger Monograph on the deep-sea fishes as "probably an inhabitant of moderate depths, although no positive evidence has been forthcoming as to its vertical distribution."

Genus **Trichiurus**, Linnæus.**Trichiurus lepturus**, Linnæus. The Silvery Hairtail. (Deep-sea.)

- Trichiurus lepturus*, . . . . ANDREWS, "Proc. Roy. Dub. Soc.," vi., p. 35.  
 ,, ,, . . . . GÜNTHER, "Chall.," vi., p. 66, and xxii., p. 39.

Several examples have occurred on the Irish coast. The Silvery Hairtail is to a great extent pelagic in habit, but was taken by the "Challenger," off Inosima, Japan, in 345 fathoms. Like the last species, it appears to be practically cosmopolitan in its horizontal distribution.

Fam.—**SCOMBRIDÆ**.Genus **Echeneis**, Artedi.**Echeneis remora**, Linnæus. The Sucking Fish.

The head and shoulders of a Sucking Fish were found in the stomach of a Picked dogfish (*Acantheas vulgaris*) taken on the S.W. coast during the survey.

We are thus able to add another to the somewhat scanty records of the occurrence of this fish in British waters.

The late Dr. Day (Fish. Gt. Brit. i. p. 107), considered that "Commerson, and some later writers" had drawn largely on the credulity of their readers in describing the use made of fish of this genus in the capture of turtle on the Mozambique coast. It may therefore be noted that the existence of what appears to be an essentially similar fishery in the Torres Straits has recently been established by the observation of Professor Haddon.

Fam.—**CARANGIDÆ**.Genus **Capros**, Lacépède.**Capros aper**, Linnæus. The Boar Fish. (Deep-sea.)

- Capros aper*, . . . . VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 360.  
 ,, ,, . . . . GÜNTHER, "Ann. Mag. Nat. Hist.," 1889, p. 417.

This species was not met with during the survey. Examples have been recorded by Günther from 180 fathoms off the S.W. coast of Ireland, and by Vaillant from the South Atlantic at a maximum depth of 192 fathoms. The Boar

fish is known to habitually frequent rather deep-water, although, in the neighbourhood of Plymouth, it is tolerably abundant in depths of less than 30 fathoms during the summer months. In 1887\* Mr. Cunningham artificially fertilized the ovum on 15th August.

Fam.—**CORYPHÆNIDÆ.**

Genus **Schedophilus**, Cocco.

**Schedophilus medusophagus**, Cocco. (Deep-sea.)

*Schedophilus medusophagus*, GÜNTHER, "Trans. Zool. Soc. Lond.," xi., 1882, p. 233.

The only known British example of this species was taken in a salmon net at Portrush, Co. Antrim. We are not aware that there exists any record of its occurrence at depths of over 100 fathoms, and, in including it among the deep-sea forms, have been guided merely by the example of Dr. Günther (Chall. xii. p. 46). From the remarks of this author it would appear that the various species of the genus are pelagic, though some possess structural characters indicative of a bathybial habitat. *S. medusophagus* has been obtained, in the adult condition, in the Mediterranean and off Samoa, as well as on the Irish coast, while young examples are common at the surface in Mid-Atlantic (Günther).

Fam.—**COTTIDÆ.**

Genus **Cottus**, Artedi.

**Cottus quadricornis**, Linnæus. (Littoral.)

*Cottus quadricornis*(?), . . . HOLT, "Trans. Roy. Dub. Soc.," N. S., v., p. 117.

The addition of this species to the Irish list rests upon the doubtful identification, by one of us, of certain very young Cotti, taken during the survey in the outer harbour at Killybegs, in Donegal Bay, and off Tory Island.

Fam.—**TRIGLIDÆ.**

Genus **Trigla**, Artedi.

**Trigla cuculus**, Linnæus. The Red Gurnard. (Deep-sea.)

*Trigla pini*, . . . . VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 360.

A specimen is recorded by Vaillant from 164 fathoms (360 metres) in the Bay of Biscay. The species is otherwise known only from littoral waters. Judging from the results of the survey, it is only moderately abundant on the west coast of Ireland.

\* "Jour. Mar. Biol. Assoc.," March, 1889.

**Trigla lyra**, Linnæus. The Piper. (Deep-sea.)

- Trigla lyra*, . . . . . VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 360.  
 ,, ,, . . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," viii., pp. 121  
 and 219.

Two adult specimens were trawled at 144 fathoms off the coast of Mayo, and a young one at 115 fathoms off the coast of Kerry. Other examples occurred during the survey at depths between 24 and 62 fathoms. Vaillant records the capture of a very small specimen from 222 fathoms in the Bay of Biscay.

Fam.—**PEDICULATI**.Genus **Lophius**, Artedi.**Lophias piscatorius**, Linnæus. The Angler. (Deep-sea.)

- Lophius piscatorius*, . . . BROWN-GOODE, "Proc. U. S. Mus.," iii., 1881, p. 469.  
 ,, ,, . . . BOURNE, "Journ. M. B. Assoc.," N. S., i., p. 310.  
 ,, ,, . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," viii., p. 219.

This species, well-known in littoral waters, appears to be regularly met with also at considerable depths. Thus Bourne obtained a specimen at 200 fathoms on the S.W. coast of Ireland; another was taken during the survey at 115 fathoms, off the coast of Kerry, while three have been recorded by Brown-Goode from the coast of the United States at depths of 120, 142, and 365 fathoms, respectively.

Fam.—**DISCOBOLI**.Genus **Liparis**, Artedi.**Liparis vulgaris**, Fleming. (Deep-sea.)

- Liparis vulgaris*, . . . GUNTHER, "Ann. Mag. Nat. Hist.," xiii., 1874, p. 139.  
 ,, ,, . . . SCHARFF, "Sci. Proc. Roy. Dub. Soc.," 1891, p. 448.

Dr. Scharff has added this fish to the Irish list since the publication of his Museum Catalogue. It was not recognised during the survey, though it may have occurred among a number of examples of this genus, too young for specific

determination, which have received attention from one of us in a previous number of these Transactions.\*

*L. vulgaris* is not included by Dr. Günther in the Challenger Monograph on Deep-sea fishes, although it had previously been recorded by the same author among the species taken by the "Porcupine" at 180 fathoms in the Faroë Channel. Beyond this, it is only known as a littoral form, but it is interesting to note that it has been taken at a depth of 64 fathoms off the Mull of Cantyre.†

Fam.—**BLENNIIDÆ.**

Genus *Carelophus*, Kröyer.

*Carelophus ascanii*, Walbaum. (Deep-sea.)

- Carelophus ascanii*, . . . STROM, "Norsk. Vid. Selsk. Skr.," 1881, p. 75.  
*Blenniops ascanii*, . . . GÜNTHER, "Ann. Mag. Nat. Hist.," 1874, p. 139.  
*Chirolophus galerita*, . . . SMITT, "Hist. Skand. Fish.," ed. ii., p. 218.

This species was not met during the survey, and has only been recorded within the Irish area from shallow water. Specimens have been taken at 180 fathoms in the Faroë Channel (Günther) at 140 fathoms in Trondjheim Fjord (Strom.), while the maximum depth at which it has been known to occur in Norwegian waters appears to be 182 fathoms (Smitt).

Fam.—**TRACHYPTERIDÆ.**

Genus *Trachypterus*, Gouan.

*Trachypterus arcticus*, Brünnér. The Northern Deal-fish. (Deep-sea.)

- Trachypterus arcticus*, . . . . DAY (?), "Zool.," February, 1875, p. 4343.

The Deal-fishes are without doubt abysmal in their normal habitat, although, as it happens, only a single example has actually been taken in deep-water (*cf.* Günther, Chall. xxii. pp. 71-72). The species under consideration is represented in Irish records by a single example washed ashore at Bundoran.

\* Holt, "Trans. Roy. Dub. Soc.," N. S., v., 1893, p. 35.

† Günther, "Proc. Roy. Soc. Edin.," 1888, xv., p. 211.

## Fam.—GOBIIDÆ.

Genus *Gobius*, Artedi.*Gobius Friesii*, Malm. (Littoral.)

(Pl. xli., fig. 3.)

- Gobius Friesii*, . . . . . MALM, "Forh. ii. Naturf. Mode.," 1873, p. 583.  
 ,, ,, . . . . . COLLETT, "Forh. vidensk. Selsk. Chra. aar. 1874.,"  
 1875, p. 154.  
 ,, ,, . . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., 1892,  
 p. 220.  
 ,, ,, . . . . . SMITT, "Hist. Skand. Fish.," ed. ii., 1893, p. 248.  
 ,, *gracilis*, . . . . . FRIES, "Vet. Akad. Handl.," 1838, p. 245.  
 ,, ,, . . . . . NILSS., "Skand. Faun.," iv., 1855, p. 224.  
 ,, *macrolepis*, . . . . . SCHARFF, "Proc. Roy. Ir. Acad.," 3rd S., i., 1891,  
 p. 458.

DIAGNOSIS OF SPECIES (Di. 6; Dii. 14–15; A. 13–15; L. lat. 25).—Body rather compressed, length of the head about  $3\frac{2}{3}$  times in the total length, without the caudal. Eye nearly one-third of the length of the head, and equal to or slightly exceeding the length of the snout. Large imbricating scales on the top of the head behind the eyes, and in regular rows on the body. Throat naked in young, clothed with small imbricating scales in old examples.

Jaws with several series of small closely set teeth, those of the outer series (of the lower, frequently of both jaws) less numerous, larger than the rest, and unciform.

Anterior ray of the first dorsal may be produced into a filament (in males?). Second dorsal and anal fin rather high, the posterior rays nearly twice as long as the anterior, and, except in young examples, extending as far as, or a little beyond, the origin of the caudal, which is large and somewhat lanceolate. The anal papilla conical.

Several conspicuous horizontal rows of dermal papillæ on the anterior part of the gill-cover. Colour brown or yellowish, with rows of darker brown or golden-yellow spots along the dorsum and the lateral line. Throat and fin-membranes with numerous minute dark specks.

The above diagnosis is formulated on the lines of the description given by Collett (*l. c.*), but certain alterations have been made in accordance with the fresh light afforded by the material collected during the survey, and by the single

specimen taken by the "Flying Falcon." According to Collett's experience only the lower jaw exhibits an outer series of larger teeth, but we find such a series present in both jaws, the teeth, moreover, being distinctly unciform in character in the larger of the Irish examples. Of the alternative colourations we have mentioned, the more brilliant appears to have been observed only by Fries, the discoverer of the species. The specimen which he obtained was stale, and he considered that it must have been more brilliantly coloured in life. No notes were taken of the Irish examples at the time of capture, but the recollection of one of us is sufficiently clear to enable us to affirm that the general colour was a dull brown, the spots being darker. Collett's experience appears to have been to the same effect.

To Dr. Scharff belongs the credit of first recognising the species as one new to the British Fauna, but it was his misfortune to obtain only a single half-grown example, which, from the very scanty information at that time available, could not with certainty be referred to *G. Friesii* or to any other form. It was accordingly described as a new species under the name of *G. macrolepis* (Scharff, *loc. cit.*).

While the Survey Collections were being sorted, the attention of one of us was drawn by Dr. Scharff to the great resemblance which several gobies, trawled in Killybegs Harbour and Cleggan Bay, bore to his type of *G. macrolepis*. The resemblance between the last named and *G. Friesii* (Malm.) had been already noted by the discoverer of the former, and he was kind enough to give us references to the literature of the species. On examining our material it became apparent that while all the Survey examples were certainly of the same species, the larger agreed best with *G. Friesii* and the smaller with *G. macrolepis*. In order to decide the question, all Irish specimens, including that taken by the "Flying Falcon," were, with Dr. Scharff's consent, submitted to the examination of Herr Collett, who, after comparing them with an undoubted example of *G. Friesii*, arrived at the conclusion that they belonged to that species. It is therefore placed beyond dispute that the differences between *G. macrolepis* and *G. Friesii* are merely developmental, and not of specific importance. The type of *G. macrolepis* measures only 7·8 cm., and is of nearly the same size as the smallest Survey example of *G. Friesii*, the specimen figured by us (Pl. XLI., fig. 3) is represented of the natural size, *i.e.* 8·8 cm., and Collett speaks of an example of 10 cm. The developmental changes which take place within such an interval of growth, as indicated by the differences in the diagnosis of *G. macrolepis* and *G. Friesii*, and illustrated by the Survey series, are chiefly as follows.—The eye becomes, as usual, relatively smaller, and the head relatively shorter as the size increases. The eyes which, in a specimen of 7·8 cm., are separated by an interval equal to one-fifth of their diameter, become so closely apposed in specimens of about 9 cm. that there is

hardly any interspace left. The throat, scaleless in the smaller examples, is clothed with minute imbricating scales in the larger ones. The height of the second dorsal and anal undergoes a relative increase, so that, whereas in young examples the extremities of the posterior rays of even the dorsal scarcely reach the origin of the caudal, in full-grown examples the posterior rays of both second dorsal and anal extend considerably beyond that point, even when erected to what appears to be the most vertical position attainable (*cf.* fig. 3). The elongation of the anterior ray of the first dorsal is a character which seems to have escaped the notice of Scandinavian writers, which is the less remarkable in that there is no constancy in its occurrence. It may, in fact, be indifferently present or absent in examples of any size with which we are acquainted. In the specimen figured the extreme point of the ray is wanting, but it does not appear probable that its original length was ever greatly in excess of that shown in the drawing. On the other hand several of our larger specimens show the ray prolonged in exactly the same way as in Scharff's figure of *G. macrolepis*. The character may be sexual, but this we are unable to affirm. It may be noted that Scharff's specimen was a mature male.

The variation in the fin-ray formula of the species does not appear to be extensive. The information at our disposal is as follows:—

Di.	6	Dii.	14	A.	14	Type specimen (Fries).
	6		15		13	Specimen of 5·9 cm. (Collett).
	6		15		15	Type of <i>G. macrolepis</i> (Scharff).
	6		15		14	} Four examples from the Survey Collection.
	6		15		14	
	6		15		(?)	
	6		14		13	

We are not disposed to regard the large number of anal rays in *G. macrolepis* as of sufficient importance to interfere with the association of the two species.

*Locality and Distribution.*—Previous to its discovery in Ireland, *G. Friesii* was only known from three specimens, from the Strömstad and Gullmar Fjords in Sweden, and Christiania Fjord in Norway. Scharff's specimen was taken at 5 fathoms on the S.W. coast of Ireland,\* while those collected during the Survey occurred in the outer harbour, Killybegs, and in Inver and Cleggan Bays, the depths ranging from 1 to 10 fathoms. In the first two of these localities the fish is probably far from rare, as several were obtained in a single haul. Smitt, who has overlooked the Irish records, considers that it is a deep-sea species, but we know of no reason for this opinion.

\* Mr. A. R. C. Newburgh informs us that he has also taken the species on the S. W. coast since the Survey was completed.

**Gobius Jeffreysii**, Günther. (Deep-sea.)

- Gobius Jeffreysii*, . . . . GÜNTHER, "Ann. Mag. Nat. Hist.," 1867, xx., p. 290,  
and 1874, xiii., p. 138.
- " " . . . . GÜNTHER, "Proc. Roy. Soc. Edin.," 1888, xvi.,  
p. 120.
- " " . . . . COLLETT, "Norg. Fisk," p. 54.
- " " . . . . LILLJEBORG, "Sverig. o. Norg. Fisk," i., p. 587.
- " " . . . . SMITT, "Hist. Skand. Fish," Ed. ii., p. 261.
- " *quadrifasciatus*, . . DAY, "Fish. Gt. Brit.," i., p. 168.

Two adult examples of this species, now for the first time recorded from Irish waters, were taken during the survey. Of these the larger, measuring 3.1 cm. was taken in Dingle Bay. The other appears by the label to have come from Kilkieran Bay, Aran Islands, Co. Galway, but we have reason to believe that the label has been accidentally changed and that the specimen was really taken off Balycottin in 41 fathoms. A large number of small gobies, which appear also to belong to this species, were trawled in August, 1890, off the Skelligs in 80 fathoms, and also off Balycottin.

The species was first taken by Jeffreys off the Hebrides, in 1867, at 80 to 90 fathoms, and was subsequently found by Wyville Thompson, at 180 fathoms in the Faroë Channel. More recently ten examples were captured by Murray in the Clyde estuary. Among these were a male and female engaged in spawning at the time of capture, which enabled Dr. Günther, who has recorded these and the previous specimens, to point out the striking differences of colour which then occur.

The female was marked and coloured in the ordinary manner, but the male, which was only one and a-half inches long had a uniformly coloured body, without spots, with fins showing most beautiful ornamentation. A figure of the breeding male accompanies Günther's description,\* while the ordinary colouration is shown in his figure of the type.† The figure given by Day is either that of Günther's type or of a specimen taken at the same time.

The species has been recorded also from Norway: from the deep-water of Stavanger Fjord by Sars, and from Haagesund by Lilljeborg. The two adult examples taken during the Survey have the ordinary colouration, but the smaller ones, perhaps two small for exact specific determination, in many cases, are almost wholly destitute of dark pigment of any description.

\* "Proc. Roy. Soc. Edinb.," *tom. cit.*, pl. iii., fig. B.

† "Ann. Mag. Nat. Hist.," 1867, xx., pl. v., fig. C.

Genus *Aphia*, Risso.*Aphia pellucida*, Nardo. (Littoral.)

- Gobius pellucidus*, . . . . NARDO, "Giorn. Fis. Chirn. Stor. Nat. Pavia,"  
1824, iii., p. 7.
- Latrunculus pellucidus*, . . GÜNTHER, "Cat. Fish. Brit. Mus.," iii., p. 556.
- " " . . . COLLETT, "Proc. Zool. Soc. Lond.," 1878, p. 319.
- Aphia pellucida*, . . . . DAY, "Fish. Gt. Brit.," i., p. 169.
- " " . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 169  
and 432.
- Atherina minuta*, . . . . RISSO, "Ichth. Nice.," p. 340.
- Aphia meridionalis*, . . . RISSO, "Fauna Eur. Merid.," iii., p. 287.
- Gobius albus*, . . . . PARNELL, "Trans. Roy. Soc.," Edinb., xiv., p. 137.
- " *Stuwitzii*, . . . . DÜBEN and KOREN, "Kgl. Vet. Akad. Förhundl.,"  
1844, p. 51.
- Slender Goby*, . . . . COUCH, "Brit. Fish.," ii., p. 172.
- Transparent Goby*, . . . . COUCH, "Brit. Fish.," p. 171.

To Collett belongs the credit of clearing up the synonymy of this remarkable form in showing that the *Gobius albus* of Parnell, and the *Gobius Stuwitzii* of Düben and Koren were but male and female of the same species; and further, in showing that the original *Gobius pellucidus* of Nardo was identical with *Gobius Stuwitzii*.

The Scandinavian author was further able (*loc. cit.*), by his exhaustive observations of the life-history, to give a most detailed description of the fish at all stages, and to reconcile the discrepancies in the descriptions of previous authors by demonstrating that such are due, especially as regards the teeth, to developmental changes and sexual dimorphism. In the nearly mature males we find, for instance, that "besides the minute teeth, there is become visible an outer row of cylindrical teeth, yet not full-grown, but having reached a greater length than the others," whereas in fully mature fish of the same sex we are told that, the minute teeth having disappeared, those that remain are "of only one kind, few in number, but long and cylindrical." The females retain throughout life the dentition characteristic of the younger stages of either sex, or, in other words, exhibit the features of *G. Stuwitzii*.

The largest male observed by Collett measured 43 mm., while no female exceeded a length of 46 mm., and the author is inclined to believe that the species is an annual vertebrate, dying at the end of the first spawning period. The survey

examples are four in number, two males and two females, all adult, and with reproductive organs fully matured. They were taken in Killybegs Harbour, on the 23rd June, 1890, and, although the same ground was carefully worked over the following year, no further examples could be met with. The largest, a male, considerably exceeds the greatest measurement given by Collett or by Day, and appears to be of unusual size. It measures 55 mm. or  $2\frac{5}{32}$  inches.

The species is known from several localities in Norway; along the Western coast of Continental Europe; and from the Mediterranean and Black Sea, in the British Isles from Solway Firth, Frith of Forth, Aberdeen, Weymouth, south and south-west coast, and Bristol Channel. The four Survey examples are the only ones recorded from Ireland.

### Genus *Crystallogobius*, Gill.

#### *Crystallogobius Nilssonii*, Düben and Koren. (Littoral.)

- Gobius Nilssonii*, . . . . DÜBEN and KOREN, "Kgl. Vit. Akad. Forhandl., Stockh.," 1844, p. 53.
- Gobiosoma Nilssonii*, . . . . GÜNTHER, "Cat. Fish. Brit. Mus.," iii., p. 86.
- Crystallogobius Nilssonii*, . . GILL, "Proc. Acad. Nat. Sci. Phil.," 1863, p. 269.
- "    "    . . . . COLLETT, "Proc. Zool. Soc. Lond.," 1878, p. 331.
- "    "    . . . . DAY, "Fish. Gt. Brit.," i., p. 172.
- "    "    . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 121, 218, 432.
- Gobius linearis*, . . . . DÜBEN and KOREN, "Ofver. Vet. Akad. Handl.," 1845, i. p. 111.

The species has been well described by Collett (*loc. cit.*).

Like the last, it has received such ample attention at the hands of Collett that reference to it, except as regards the distribution, is unnecessary. Previous to the Survey we believe that only two specimens had been recognised from British waters, viz. one taken by Thomas Edwards in a rock pool at Banff,\* in 1868, and another recorded in the Naturalists' column of the *Field* probably by Dr. Day.

During the cruise of the "Fingal" a great number were taken in Ballinskelligs Bay, while others were found in the stomachs of larger fish in Galway Bay. In the following year the use of suitable nets demonstrated that the species occurred in abundance along practically the whole of the western coast, at depths from 10 to 41 fathoms, the additional localities being the Kenmare River†,

\* Smiles, "Life of a Scotch Naturalist," pp. 375 to 427.

† It should be remembered that this so-called river is really an arm of the sea, and not an estuary

Ballynakill Bay, Davalann, Clew Bay, Broadhaven Bay, Killybegs outer harbour, and Sheephaven. Shortly after the capture of the "Fingal," specimens had been announced by one of us. The occurrence of the species in large numbers off the Eddystone Lighthouse was recorded by Cunningham, who conjectured (*loc. cit.*) that it was "fairly abundant between 20 and 30 fathoms, on smooth sandy ground, all along the British and Irish coasts." The surmise, in addition to the confirmation it had already received by the (then unpublished) results of the "Harlequin" investigations, has since been borne out by the experience of one of us in the North Sea, where *C. Nilssonii* has been taken off Flamborough Head; while fragments which almost certainly belong to the same species have been seen adhering to the trawls of vessels returning from other grounds. It may be noted, as shown by the results of the Survey, that the vertical range is rather more extensive than was supposed by Mr. Cunningham, while the fish occurs on muddy as well as on sandy ground.

It is known to occur on the Scandinavian coast as far North as Christiansund, but does not appear to have been recognised in any other locality except those already mentioned. Day, in the light of the information at his disposal, considered it to be evidently much rarer than *Aphia pellucida*, and partial to more northern localities. It is certainly infinitely more numerous than *Aphia* on British coasts; and it seems very probable that the limited extent of its known horizontal range is in great part due to the ease with which it may be mistaken for the young condition of some larger fish.

It does not appear that *C. Nilssonii* has ever been utilised as human food, although, like the preceding species, it might probably be procured in sufficient quantities to serve as "white bait." Its importance as food for other fishes was adverted to some years ago, by a writer in the *Field* newspaper, and is sufficiently emphasised by the frequency with which the species figures in the list of organisms taken from the stomachs of larger forms during the Survey.\*

#### Genus *Callionymus*, Linnæus.

##### *Callionymus lyra*, Linnæus. The Dragonet. (Deep-sea.)

*Callionymus lyra*, . . . . VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 349.  
 ,, ,, . . . . SMITT, "Hist. Skand. Fish.," ed. ii. p. 273.

The species appears to be common along the west coast of Ireland. It was not met with at more than 62 fathoms, and has never been recorded from below the 100-fathom line in British waters. Vaillant, however, found it at 130 fathoms off

\* Cf. Holt, "On the Food of Fishes on the West Coast."—Sci. Proc., iv., pp. 457-471.

the coast of Portugal, and at 218 fathoms in the Bay of Biscay; while Smitt mentions an example in the Royal Museum of Norway, said to have been taken at 100 to 200 fathoms, off the Jutland Reef. It is, therefore, in accordance with the plan of this Paper, placed amongst the deep-sea fishes; whereas *C. maculatus*, though not improbably more bathybial in its general distribution on our own coasts, has to be relegated to the littoral species; a circumstance which sufficiently illustrates the difficulty of drawing a hard-and-fast distinction between the two classes.

It is noted by Dr. Günther\* that the mature male is not found in such shallow water as the female or young; and our own experience supports the general accuracy of this statement. We have, however, received a fully mature male from Tetney, a part of the Humber estuary where the depth is, at the most, five fathoms. Day† states that the fish “does not appear to congregate in shoals,” a remark which applies, if at all, only to the adults, since great numbers of young and half-grown examples were taken during the Survey in Inishbofin Harbour, while about 100 have frequently been taken by one of us in a single haul of the shrimp-trawl on the Humber ground already referred to.

The synonymy of the species is now so generally understood that it is unnecessary for us to make more than a passing allusion to the fact that the female and young were long regarded as distinct;‡ and it appears to us that such descriptive observations as we have to make may be most conveniently reserved for comparison with the next species.

\* “Cat. Fish. Brit. Mus.” iii. p. 369.

† “Fish. Gt. Brit.” i. p. 176.

‡ Male, . . . . . *C. lyra*. Linn., “Syst. Nat.” i. p. 433, *et auct. plur.*

„ . . . . . *Uranoscopus lyra*. Gronov. ed. Gray, p. 42.

Female and young, . . . . . *C. dracunculus*. Linn., *loc. cit.*, *et auct. plur.*

„ „ . . . . . *U. dracunculus*. Gronov. ed. Gray, *loc. cit.*

Young (?), . . . . . *C. elegans*. Lesueur, “Bull. Soc. Phil. Paris,” 1814, p. 6.

Young male, . . . . . *U. micropterygius*. Gronov. ed. Gray, *loc. cit.*

**Callionymus maculatus**, Bonaparte. (Littoral.)

- |                                |                          |  |
|--------------------------------|--------------------------|--|
| <i>Callionymus maculatus</i> , | . . .                    | BONAPARTE, "Faun. Ital. Pesc.," figs. 2 and 3.                     |
| "                              | " . . .                  | GÜNTHER, "Ann. Mag. Nat. Hist.," 1867, vol. xx.,<br>p. 290.        |
| "                              | " . . .                  | DAY, "Fish. Gt. Brit.," vol. i., p. 177.                           |
| "                              | " . . .                  | LILLEJBORG, "Sverig. o. Norg. Fisk.," p. 666.                      |
| "                              | " . . .                  | GÜNTHER, "P. R. S. Edinb.," xv., p. 211.                           |
| "                              | " . . .                  | HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., p. 218.                   |
| "                              | " . . .                  | SMITT, "Hist. Skand. Fish.," ed. 2, p. 279.                        |
| "                              | <i>lyra</i> , . . .      | RISSO, "Ich. Nice," p. 113.  |
| "                              | <i>dracunculus</i> , . . | BRÜNNER, "Pisc. Mass.," p. 17.                                     |
| "                              | " . . .                  | CUVIER, "Règne Anim."  |
| "                              | <i>cithara</i> , . . .   | CUVIER et VALENCIENNES, "Hist. Nat. Poiss.,"<br>vol. xii., p. 280. |
| "                              | <i>reticulatus</i> , . . | CUVIER et VALENCIENNES, "Hist. Nat. Poiss.,"<br>vol. xii., p. 284. |

DIAGNOSIS OF SPECIES.—The horizontal diameter of the eye rather longer in the male, rather shorter in the female, than the length of the snout, without the protrusible mouth.

This appears to be the most salient character distinguishing this from the commoner species, *C. lyra*, in which the length of the snout considerably exceeds the horizontal diameter of the eye in both sexes, except in the very youngest stages.

So closely allied are the two forms that it seems to us that any useful description of the one must contain frequent comparison with the other. Moreover, in both, the male differs so much from the female that it is necessary to describe the sexes separately, and though this has been excellently done by Lilljeborg, British authors have hitherto contented themselves with pointing out the difference in the length of the first dorsal fin and in the colouration. These features, however, are only apparent in adults; and a description of the pigmentation is chiefly valuable to those who have the opportunity of observing specimens in the fresh condition.

The two species differ considerably in size, the commoner, *C. lyra*, attaining a length of about twelve inches, whilst *C. maculatus* appears never to greatly exceed a length of six inches. Hence it follows that the more conspicuous features of sexual dimorphism are attained at different sizes, so that a male of the smaller form exhibits the full adult characters at a size at which one of the larger is still in

that respect immature. We are not in a position to affirm any exact size at which the elongation of the dorsal commences in either species, and, no doubt, in this respect there is considerable variation; but amongst the examples before us a male of *C. maculatus* is fully mature at  $4\frac{1}{8}$  inches, whereas the smallest male of *C. lyra* which exhibits any (external) approach to maturity is  $4\frac{7}{8}$  inches long. There is thus a possibility, in so far as concerns the elongation of the dorsal, of confusion between a mature female of *C. maculatus* and an immature male of *C. lyra*, to avoid which, in the absence of any very well-marked differences in colouration, a somewhat close inspection of minor characters is necessary, and we believe that the subjoined Table of dimensions and remarks will be found of use.

*C. maculatus.* (Adult.)

MALE.	FEMALE.
Length of head to total length without caudal fin, . . . . . 1 to $3\frac{3}{4}$	Length of head to total length without caudal fin, . . . . . 1 to $3\frac{1}{2}$
Horizontal diameter of eye to length of head, . . . . . 1 to $3\frac{1}{2}$	Horizontal diameter of eye to length of head, . . . . . 1 to $2\frac{1}{2}$
Length of snout (exclusive of protractile mouth) to horizontal diameter of eye, . . . . . $1\frac{1}{3}$ to 1	Length of snout (exclusive of protractile mouth) to horizontal diameter of eye, . . . . . 1 to $1\frac{1}{2}$
Width of interorbital space to horizontal diameter of eye, . . . . . 1 to 5 ca.	Width of interorbital space to horizontal diameter of eye, . . . . . 1 to 6 ca.
Anterior dorsal ray elongated, reaching the middle of second dorsal.	Anterior dorsal ray not elongated.

The second dorsal fin of the adult male is considerably higher in *C. maculatus* than in *C. lyra*. In a specimen of the former,  $4\frac{1}{8}$  inches long, the first ray of the fin mentioned is contained not quite 3 times in the total length, without the caudal. In three specimens of *C. lyra*, exhibiting the full development of the first dorsal, and measuring respectively  $4\frac{7}{8}$ ,  $7\frac{1}{2}$ , and 9 inches, the same ray is contained  $5\frac{3}{4}$ , 5, and 6 times in the total, without the caudal. In males of both species, according to Lilljeborg's description and our own experience, the second dorsal fin is highest posteriorly, although Day's figure of the male *C. maculatus* shows this fin highest in front. It is of about equal height throughout in females of both species. The first ray of the first dorsal in fully adult males of *C. lyra* extends back as far as the caudal, but of course intermediate stages occur, necessitating a recourse to other characters for specific determination. Such are furnished by the proportions of the eye and snout, which differ considerably in the two species, since in the adult male *C. lyra* the horizontal diameter of the eye is contained  $2\frac{1}{2}$ , in the adult female  $1\frac{1}{4}$  times in the length of the snout (exclusive of the protractile mouth

apparatus). It is thus comparatively easy to distinguish the two species if examples of the same sex are compared, but the difference between a mature male of the smaller and an immature female of the larger species is not very conspicuous so far as these proportions are concerned. In this case, however, the characters of the dorsal fin will serve to obviate any confusion.

Since the proportions of the eye vary to some extent with the growth of the fish it may be supposed that those which we have given above as characteristic of the adult stages of *C. lyra* may not be available in distinguishing young examples of this species from specimens of *C. maculatus* of an equal size. As a matter of fact, however, there is little risk of confusion, as we may illustrate by comparing a mature female *C. maculatus* with the female *C. lyra* which, in our collection, presents the nearest approach to it in size. The former measures 6.1 cm., and the latter 5.4 cm. (the caudal being excluded in both cases). As the proportion of the eye varies in inverse ratio with the size of the individual, it is obvious that the contrast will be less marked (the smaller specimen belonging to the species characterised by the smaller eye) than if the two were of the same size. Still in *C. maculatus* we find the eye .6 cm. and the snout (without the protractile mouth apparatus) only .4 cm., whereas in *C. lyra* the dimensions are respectively .50 and .55 cm. Thus in *C. maculatus* the eye is half as long again as the snout, which in the other species exceeds the eye by one-tenth. Moreover, the distance between the tip of the mandible and the vent is contained  $2\frac{1}{2}$  times in the total without the caudal in *C. maculatus*, in *C. lyra* only 2 times. The caudal region is much thicker in the former, and the eyes much closer together; and although such actual approximation seems to some extent a feature of individual variation, the width of the interorbital space relatively to the length of the eye is always much less in *C. maculatus* than in *C. lyra*.

We note further that in a large series of *C. lyra*, of about the same size as, or a little smaller than, the one we have been dealing with, the opercular trident is constantly masked with skin except at the extremities of the denticles. In the adults of *C. maculatus*, corresponding in size to these last, the trident is entirely naked. The state of the specimens shows that this is natural, but a similar condition might so easily manifest itself in abraded examples of *C. lyra* that little weight should be attached to the character in cases of doubtful identity.

The brilliant colouration of the adult male of *C. lyra* is closely imitated, so far as general tints are concerned, by the adult male of the smaller species. The latter, however, is readily distinguished by the markings of the second dorsal fin alone. On this fin there are four longitudinal rows of conspicuous dark spots, crossed by a number of vertical rows of light markings, each with a narrow, dark outline. The same fin in *C. lyra* merely exhibits four indistinct, dark, longitudinal bands. The female of *C. maculatus* has the second dorsal profusely speckled with dark

markings, a condition not observable at any stage of either sex of the larger species. The body markings of adult males fade rapidly in alcohol, but those of the fins remain recognisable for a considerable time.

The sexual differences of proportion tend to disappear as the size diminishes, but the specific characters of the eye and snout are available for diagnosis from a very early age, the snout being longer than the eye in specimens of *C. lyra*, not more than an inch long. In colour, young examples usually resemble the adult female; but we have seen specimens of *C. lyra*, from 3 to 4 inches long, which were brilliantly marked with green purple and crimson. These were taken from a ground in the Humber estuary; and, from the colouration of flat fish on the same ground, we conclude that the markings were explicable by the nature of the bottom: in any case they were in no way sexual.

The fin-ray formula is of no assistance in distinguishing the two species, as may be seen from the subjoined enumeration.

*C. maculatus.*

Di. 4.            Dii. 9-10.            A. 8-9.            Pelv.  $\frac{1}{5}$ .

*C. lyra.*

Di. 4.            Dii. 9.            A. 9.            Pelv.  $\frac{1}{5}$ .

In speaking above of "mature" and "immature" examples we have used the terms only in reference to the external characters. We are unable to say, from our own knowledge, that these features of sexual dimorphism are, or are not, habitually assumed, *pari passu*, with sexual maturity; but it appears from an observation of Dr. G. Johnston,\* that the male may be sexually mature before the fin becomes elongated. It is noteworthy that in *Arnoglossus laterna*, a species in which (if we are right in supporting Cunningham's contention of the identity of *A. laterna* and *A. lophotes*) the dimorphism affects the same structures as in *Callionymus*, sexual maturity is attained (commonly, if not universally) long before the dimorphism is apparent.

*Locality and Distribution.*—Previous to the Survey, *C. maculatus* had not been recorded from Irish waters. It was first established as British by Dr. Günther,† three specimens having been obtained in the Hebrides from depths of 80-90 fathoms. Since then several have been taken by Dr. John Murray in 26 fathoms in the Clyde Estuary,‡ the largest measuring four and a-half inches. Of our own

\* Zool. Journal, iii., p. 366. The observations refer to *C. lyra*.

† Günther, Ann. Mag. Nat. Hist., 1867, xx., p. 290.

‡ Günther, Proc. Roy. Soc. Edin., 1888, xv., p. 211.

examples, a mature male and female came from 38 fathoms, off Gregory Sound; a mature female from 41 fathoms, off Valentia; and a mature male most probably from 30 to 19 fathoms in Donegal Bay, the label, unfortunately, being in this case wanting. Two small examples, from 41 fathoms off Valentia, and 80 fathoms off the Skelligs, prove, on re-examination, to belong also to this species.\* *C. maculatus* has been met with also in Norwegian waters, and off the coast of Denmark, while it is common in the Mediterranean. It seems probable that, in northern latitudes, it occasionally passes the 100-fathoms line, but we are acquainted with no record to that effect.

Fam.—GADIDÆ.

Genus *Gadus*, Artedi.

*Gadus morrhua*, Linnæus. The Cod. (Deep-sea.)

During the survey this species was only met with in shallow water or at moderate depths, but it is known to descend beyond the 100-fathoms line on the coast of Norway.† Günther (Chall. xxii., p. 82) remarks that cod-fish retire during the summer months into deeper water; but, according to our information, it appears that they are abundant all the year round off the Faroë Islands at depths exceeding 100 fathoms.

*Gadus æglefinus*, Linnæus. The Haddock. (Deep-sea.)

As already recorded by one of us,‡ haddocks were taken both in the trawl and on the long lines at 154 fathoms, 28 miles off Achill Head, on the 20th April, 1891. So far as we are aware this is the only exact record of the occurrence of the species in deep water, but we believe that it is commonly taken at considerable depths off the Faroë Islands.

*Gadus merlangus*, Linnæus. The Whiting. (Littoral.)

Among the whiting taken during the Survey was a fully adult specimen having a distinct, though small, barbel. The presence of this appendage in very young specimens has been frequently referred to by authors. The condition of the adult under consideration shows that the absence of the barbel cannot be insisted upon as invariable.

\* They were previously recorded by one of us as *C. lyra*, Sci. Proc. Roy. Dubl. Soc., p. 433.

† Lilljeborg, "Sverig. o. Norg. Fisk," p. 31.

‡ Holt, "Sci. Proc. Roy. Dubl. Soc.," vii., pp. 219, 272, 273.

Sub-genus **Boreogadus**, Günther.**Gadus poutassou**, Risso. The Poutassou. (Deep-sea.)

On the 10th July, 1890, while the trawl of the S.S. "Fingal" was down at 175 fathoms, thirty-four miles off Achill Head, a large shoal of young Poutassou was observed at the surface. They were darting violently about, and a number were easily captured in a large tow-net. According to the mate, who was the first to observe them, they were being chased by a large squid, which, however, had disappeared by the time the attention of Mr. Green and Professor Haddon had been called to them. The fish captured were carefully examined by one of us a few minutes afterwards, but they presented no sign, by distension of the air-bladder or otherwise, of having been driven upwards from any considerable depth. It may therefore be supposed that, previous to their disturbance, the fish were swimming at or near the surface. The stomachs were full of small crustaceans, copepods, etc. In the fresh condition the dorsum was a dark greenish grey, the sides silvery.

All the specimens taken were much alike in size, the total length ranging from  $5\frac{1}{2}$  to 6 inches. Day\* figures a specimen about an inch longer, but the most satisfactory figure with which we are acquainted is that given by Vinciguerra.†

The poutassou, first recorded from the Mediterranean, where it appears to inhabit considerable depths, is said to occur not infrequently on the Scandinavian coast, in the proximity of the 100-fathoms line (Collett and Lilljeborg). Though comparatively little known as a British form, it has nevertheless been already reported from the coast of Ireland (Macandrew and W. Andrews). It has also been found off North Uist (M'Intosh), in the Hebrides, and on several occasions large shoals, consisting apparently of young fish only,‡ have been observed on the south-west coast of England, though there is no evidence that the species is permanently resident in that locality. Thus, while, as Günther remarks,§ the fish habitually lives in somewhat deeper water than its congeners, it seems probable that in its immature condition it is to a great extent pelagic and migratory.

\* "Fish. Gt. Brit.," pl. lxxxiii.

† "Ann. Mus. Genov.," xviii., p. 550.

‡ Cf. Couch, "Brit. Fish.," iii., p. 77, and Day, "Fish. Gt. Brit.," i., p. 293 (quotes Dunn of Mevagissy).

§ "Chall.," xxiii., p. 82.

**Gadus Esmarkii**, NILSSON. The Norway Pout. (Deep-sea.)

<i>Gadus minutus</i> ,	. . . .	ESMARK, "Forh. Nat. Möti i Christ.," 1844, p. 231.
<i>Gadus Esmarkii</i> ,	. . . .	NILSSON, "Skand. Fauna," iv., p. 565.
" "	. . . .	GÜNTHER, "Cat. Fish. Brit. Mus.," iv., p. 337.
" "	. . . .	SMITT, "Hist. Skand. Fisk," ed. 2, p. 508.
" "	. . . .	HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 122, 219, 438.

DIAGNOSIS OF SPECIES.\* (Di. 14–16; Dii. 22–26; Diii. 22–27. Ai. 26–30. Aii. 23–28).—Lower jaw projecting beyond the upper; teeth of the outer series of the upper jaw a little larger than the inner ones. The length of the head contained about four times in the total length, without the caudal, and greater than the height of the body, which is about two-ninths of the same dimensions. The length of the eye about one-third of the length of the head, and equal, or nearly equal to the length of the snout. The height of the caudal peduncle less than the vertical diameter of the eye, which is about one-third greater than the width of the interorbital space; the latter with a median groove. Dorsal fins separated by narrow interspaces, the greatest height of the body opposite the first; the anus at, or near, a vertical line passing between the first and second dorsals. The two outer pelvic rays produced to filaments, of which the longer may extend as far back as the anus. Barbel slender, not more than half the length of the eye. Scales small, imbricating; lateral line with a gentle curve in its anterior region.

*Colours*.—Greyish brown on the dorsum, dull silvery on the sides, pale on the ventral abdominal region.

The occurrence of this species in British waters was first noted by Günther in 1888.† In the descriptive remarks appended to his record, the author notes certain differences which occur between the specimens under his consideration (from the west coast of Scotland), and some larger specimens in the British Museum, communicated by Collett from Norway. Notably he finds that the Scotch specimens are stouter in general form, and that the eye in the Norwegian specimens is considerably larger in proportion to the size of the head.

The material in the Survey collections comprises twelve examples, which vary considerably, not only in size but in proportion; and it is important to notice that while some partake of the stout character of the Scottish forms, others agree much

\* An excellent figure is given by Dr. Günther, Proc. Roy. Soc. Edinb., xv., 1888, Pl. iii. A.

† "Proc. R. S. E.," *loc. cit.*

more with the Scandinavian. The relation of height to length of body may be taken as an instance. In a specimen nearly 4 inches (10 c.m.) in total length, taken off the Galway Aran Islands, the length, exclusive of the caudal fin, is  $4\frac{1}{2}$  times the height, whereas in one of  $6\frac{5}{16}$  inches (16 c.m.), taken off the Kenmare River, the length is  $5\frac{3}{4}$  times the height. The largest example of the series, however, a fine specimen of  $7\frac{1}{2}$  inches (19 cm.), taken at 144 fathoms, 15 mi., north-west of Achill Head, agrees in this respect with the specimen of 10 cm., and therefore with the Scottish forms studied by Dr. Günther. On the other hand, in the proportions of the eye and head, the example of  $7\frac{1}{2}$  inches, distinctly resembles the Norwegian condition, since the eye is one-third of the length of the head, and equal in length to the preorbital region, when the mouth is closed. The barbel is less than half the length of the eye.

The smaller Irish specimens agree with those from Scotch waters in the comparatively small size of the eye, and, since the dimensions of that organ, in the development of an individual, varies in inverse ratio with the total length, it must be taken that the difference is indicative of a variation of proportion, and not of developmental change. The resemblances, nevertheless, appear to us so much more striking than the discrepancies, that we have no hesitation in adopting Dr. Günther's conclusion that they are not of specific value. Moreover, although by taking the *greatest* height of the body as a standard, our largest example appears identical in proportions with the smaller, the general appearance is decidedly more slender. The smaller specimens resemble *G. minutus* rather closely, and might readily be mistaken for examples of that species; but the larger have distinctly assumed the elongate form characteristic of all members of the sub-genus *Boreogadus*, and exemplified, among the forms under consideration in this paper, by *G. poutassou*. The latter, however, is distinguished at a glance from the species before us by the greater interspace between the second and third dorsals, as well as by other characters hardly less striking.

In both *G. Esmarkii* and *G. argenteus*, the caudal peduncle is more slender than in most *Gadi* which inhabit chiefly the more littoral regions. This slenderness is of interest, since it may possibly indicate a progression towards the typical condition of so many genera of deep-sea Gadoids, where the caudal region tapers away to a point, and bears no true caudal fin.

The Irish examples yield the following fin-ray formula:—D. 14–16, 23–25, 22–23; A. 26–29, 23–25; but, in enumerating the formula in our diagnosis, we have made use of all available information on the subject. It appears that such variation as exists is not of local importance, since the maximum and minimum number of rays have been observed, respectively, in Scandinavian specimens by Smitt and Lilljeborg.

The body cavity is lined with a dense black peritoneum, and extends to a

point somewhat behind the middle of the first anal fin. In our largest example; a female taken in July, the left lobe of the liver is enormously developed, and occupies the whole of the left side of the cavity. The ovaries, in this example, are of comparatively small size, spawning having been probably accomplished some considerable time previous to capture. It has already been noted by one of us\* that the female is mature at a length of about 4 inches, and it is possible that maturity may be attained at even as smaller size, since Günther speaks of the Scotch specimens, which were from  $3\frac{1}{2}$  to 7 inches long, as having the ovaries much expanded. The ova, and probable larva, have already been described in these Transactions.† The maximum size reached by the species is uncertain, but it is evidently not considerable. The largest specimen observed by Collett measured  $9\frac{1}{2}$  inches (24 cm.).

*Locality and Distribution.*—The Norway Pout appears to be entirely confined to the waters of Northern Europe. On the coast of Scandinavia it appears to be fairly plentiful, but local; the recorded localities, according to Smitt, being the Christiania, Trondhjem, Strömstad, Dynchil, and Säche fjords. Lütken has reported it from the Faroë Islands. On the west coast of Scotland it was recognised by Günther in the collections made by Mr. Murray from Kilbrennan Sound, Sanda, Lower Loch Fyne, the Sound of Mull, the Mull of Cantyre, Upper Loch Nevis, Loch Sunart, and Loch Aber. During the Survey a number were taken,‡ either in the nets or from the stomachs of larger fish, off the Kenmare River, the Aran Islands, Clare Island, and Achill Head.

The species is met with in Norway in deep water, but there appears to be no exact record of the depth. The Scotch examples were taken between 26 and 80 fathoms, and the Irish between 38 and 50, with the exception of one, trawled at 144 fathoms. It had not previously been observed in Irish waters, nor exactly recorded from below the 100-fathom line. Subsequent to the Survey, the species has been reported by one of us from the Great Fisher Bank in the North Sea.

#### Sub-genus *Gadiculus*.

Jaws sub-equal, cleft of the mouth highly oblique; head, in adult, deeply sculptured with muciferous cavities; a scaleless fossa on the nape; scales rather large, deciduous. Teeth small, in a narrow band; vomerine teeth present only in young examples.

\* "Sci. Proc.," vii., p. 399.

† S. iii., v., p. 54.

‡ Cf. "Sci. Proc.," vii., p. 438.

Gadus argenteus, Guichenot. The Silvery Pout. (Deep-sea.)

(Pl. xli., figs. 1 and 1a.)

- Gadiculus argenteus*, . . . GUICHENOT, "Explor. Algér. Poiss.," p. 102.  
 " " . . . GÜNTHER, "Cat. Fish. Brit. Mus.," viii., p. 341.  
*Gadus argenteus*, . . . GÜNTHER, "Ann. Mag. Nat. Hist.," 1874, p. 138.  
 " " . . . DAY, "Zoologist," vol. xliii., p. 312.  
 " " . . . BOURNE, "Jour. M. B. A." (N. S.), vol. i., p. 310.  
 " " . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vol. vii.,  
 p. 122.  
*Merlangus argenteus*, . . . VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 302.

Guichenot's original genus *Gadiculus*, which was based, in part, on the avowed absence of vomerine teeth, was overthrown by Günther's discovery of such teeth in the specimen taken by the "Porcupine" off the S. W. of Ireland, in 1867. The species under consideration, the only representative, had therefore to lapse to the genus *Gadus*, and, in the existing classification, could only be placed in the sub-genus *Pollachius*. In our opinion, however, the fish exhibits so many important peculiarities as to justify the creation, for its reception, of a new sub-genus, which we have defined above. It is certainly the most aberrant of the Gadi, the character of specialization being essentially in the direction associated with an abysmal habitat, although it is not actually confined to depths beyond the reach of surface influences.

The muciferous cavities, so far as can be judged from a careful examination of many specimens, both in the fresh and preserved conditions, appear to be entirely exposed to the action of the water, with no enveloping membrane. It must be added, however, that all were more or less injured, the scales, and in some cases, great part of the skin, having been frayed off, a result, no doubt, attributable to the presence of an enormous number of "Sea Urchins"\* in the trawl. The specimen figured (Pl. xli., fig. 1) is the most perfect in the Survey Collection, and was taken from the stomach of a larger fish. It is the only one which permits of a computation of the number of rows of scales crossing the lateral line, in this case 59.

The muciferous cavities (fig. 1a) are much more conspicuous in adults than in small examples, but they can be distinguished in specimens only  $1\frac{3}{4}$  inch long. Such, however, do not show the scaleless fossa on the nape, while the posterior

\* *Spatangus Raschii*.

median cavity of the occiput is relatively narrower than in full-grown fish. Specimens of an inch exhibit only the cavities of the snout. The obliquity of the jaws is a feature which appears also to increase with the growth of the individual.

Examples of less than 3 inches show very little coloration, except the silvery pigment of the sides of the head and abdomen; but the top of the head and the dorsum are speckled with dark chromatophores. These, in specimens of about an inch, show a tendency towards an arrangement into five short transverse bars, of which some traces remain in specimens of 3 inches. Larger examples show the general dull silvery coloration so well depicted in Guichenot's figure of the type.

From the examination of our specimens it appears that vomerine teeth are always present in young examples, though are few in number and loosely attached. They are altogether wanting in many of our larger specimens. The species is thus common along the west coast of Ireland at suitable depths, and is evidently there gregarious at all stages of its existence, as also, according to Vaillant, in the regions explored by the "Talisman" and "Travailleur." The importance to be attached to the occurrence of only young examples, on the Irish coast, above the 100-fathoms line may perhaps be overrated, since the net in which they were caught was a small shrimp trawl,\* which might well be evaded by larger examples. The absence of small examples from greater depths may very probably mean nothing more than that the meshes of the larger trawls were not fine enough to retain them. At the same time it must be noted that fishes at least as active as full-grown *G. argenteus* were not infrequently taken in the small net, while it is probable that, if any quantity of small examples had passed through the meshes of the larger trawls, some would have been found adhering to the spines of the Spatangi. It is also possible that the comparatively late development of the mucous cavities of the head may be in relation to some developmental change in the vertical habitat of the species. As we have seen above, it is one which lives, as it were, on the borders of the abyss, never rising into quite shallow water, and never, apparently, penetrating into very great depths.

#### Genus **Mora**, Risso.

Body moderately elongate, covered with scales of moderate size. A separate caudal; two dorsal and two anal fins; ventrals composed of six rays. Teeth small, curdiform, of equal size, in the upper jaw in a band; teeth on the vomer and sometimes on the palatine bones. Branchiostegals seven. (Günther.)

\* Sts. 114 and 115.

**Mora mediterranea**, Risso. (Deep-sea.)

(Pl. XXXIX., fig. 3; Pl. XLIV., A and A'.)

<i>Mora mediterranea</i> ,	. . .	RISSO, "Ichth. Nice.," p. 116.
" "	. . .	BONAPARTE, "Faun. Ital. Pesc.," pl. xxiii., fig. 1.
" "	. . .	CANESTRINI, "Arch. Zool.," ii., p. 359, pl. xi., xii.
<i>Asellus canariensis</i> ,	. . .	VALENCIENNES, Webb. et Beeth., "Hist. Nat. d. Iles Canar. Poiss.," p. 76, pl. xiv., fig. 3.
<i>Mora mediterranea</i> ,	. . .	LOWE, "Proc. Zool. Soc. Lond.," 1843, p. 91.
" "	. . .	GÜNTHER, "Cat. Fish. Brit. Mus.," 1860, vol. iv., p. 342.
" "	. . .	CAPELLO, "Peix de Port.," 1880, p. 30, No. 141.
" "	. . .	VAILLANT, "Exp. Sci. dei Trav. et d. Talism., Poiss.," Paris, 1888, p. 298.
" "	. . .	HOLT, "Proc. Roy. Soc.," vol. vii., 1891, p. 122.

*Synonymy of Young Examples.*

<i>Pharopteryx benoit</i> ,	. . .	RÜPPELL, "Verzeichn. Mus. Senckent. Fische," p. 16.
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DIAGNOSIS OF SPECIES. (Br. vii. : D. 7–8 / 42–44; A. 15–18 (+ 3)\* / 15–20; L. lat. 87–95. Vert. 51†).—Barbel slender, black, much shorter than eye. Both anal fins below posterior two-thirds of second dorsal, sub-continuous, the apparent interspace occupied by three minute rays. Anterior ray of first dorsal produced into a short filament. Margin of second dorsal indented. Two outer rays of pelvic fin filamentous, the second ray the longer, reaching beyond anus which is situated slightly anterior to the median point. Lateral line slightly curved at anterior region. Scales large cycloid, longer than broad.

Length of head about  $4\frac{1}{2}$  to  $4\frac{2}{3}$  in length of fish without caudal. Total length of fish fully  $5\frac{1}{2}$  times extreme depth. Diameter of eye,  $3-3\frac{1}{3}$  in length of head, greater than snout.

Interorbital space  $\frac{1}{4}$  in length of head in adults. Snout broad, obtuse. Upper jaw the longer. Opening of mouth extending to beneath centre of eye. Teeth of both jaws cardiform, in bands, widest anteriorly. A toothless interspace at anterior

\* The three minute rays, included in the bracket, may be omitted from the formula, as appears to have been done by previous writers. They appear to us to be connected with the first anal fin, if specially with either.

† The number of vertebræ is taken from Günther (Cat., vol. iv., p. 342).

angle of upper jaw, for reception of a prominence on mandibular symphysis. Cardiform teeth on vomers, slightly more conspicuous than those of jaws. Cardiform teeth also on palatines, except in very young examples.\*

Colour, brownish grey on back, dull silvery grey on sides and belly,† antero-superior region of first, and margin of second dorsal fins, black or dark grey. Pectorals and caudals, black or dark grey. Pelvics and anals, light grey. Jaws, black or dark grey; mouth, black.

*Locality and Distribution.*—Only three specimens were taken, all in one haul of the trawl at 500 fathoms, fifty miles off Achill Head, Co. Mayo, on the 10th July, 1890. As the trawl was only shot on one other occasion at a similar depth, and was then reversed for certainly some part of its course, it is impossible to form any opinion as to the abundance or rarity of the species off the west coast of Ireland at such depths, but the negative evidence of a number of hauls seems to show that it is certainly not common nearer the 100-fathom line.

The species was known to have a considerable horizontal range, but had not previously been taken north of the Bay of Biscay, whilst its absence from the collections of the “Porcupine,” “Knight Errant,” and “Triton,” and of the Norwegian North Atlantic expedition renders it probable that the western coasts of Great Britain are about the most northerly point to which it extends. On the other hand it is known to exist as far south as the Canary Islands (Valenciennes and Vaillant), and to extend also into the Mediterranean (Risso and Bonaparte). It is also known from Madeira (Lowe), and from the coast of Portugal (Capello and Vaillant). The author last quoted is our authority for its occurrence in the Bay of Biscay. Dr. Günther (“Challenger,” vol. xxii. p. 83) remarks that the specimens taken by the “Challenger” were unfortunately destroyed on board, but does not state the locality of capture.

The species appears to be exclusively confined to deep water in whatever latitude. According to Valenciennes, it used to be regularly fished for off the Canaries at depths of 100 to 200 fathoms; Lowe found it at 300 or 400 fathoms off Madeira, but Vaillant, whose records deal in all with the capture of twenty specimens, found none at less than 332 fathoms, and extended the known limits of its range to 740 fathoms. We have no information as to the maximum size reached by this species, but the largest specimen taken during the cruises of the “Travailleur” and “Talisman” appears to have measured 42 cm. in length, *i.e.* 30 cm. smaller than the largest specimen taken during the Survey. This large

\* Doubts were expressed by Günther in 1860 as to whether the absence of teeth from the palatines (in virtue of which Rüppell established his species *Pharopteryx benoit*) was really of specific value; and Valliant has since been able to demonstrate, from material collected by the “Talisman” and “Travailleur,” that the character has merely a developmental significance.

† There was no trace in our specimens of the greenish colour shown in Bonaparte’s figure.

The snout is obtuse, bluntly equilateral as seen from above. The upper jaw is distinctly longer than the lower, and the angle of the somewhat oblique gape is a little in front of the level of the centre of the eye. The head reaches its greatest height just behind the eyes, and its greatest width about the middle of the gill-cover. The body is highest and widest at about the middle of the first dorsal; thence the height decreases gradually towards the anal region, and thereafter more rapidly, until, at the caudal peduncle, it is less than the length of the snout. The peduncle terminates, amongst the insertions of the caudal rays, in a lanceolate process. Its total length, from the end of the 2nd dorsal, is 5.5 cm., and from the

end of the 2nd anal, 8 cm., since the last-named fin does not extend quite so far back as the dorsal.

*Fins.* (D. I. 8; D. II. 44; A. I. 17 (+ 3); A. II. 20; P. 19; Pelv. 6, Caud. 38, *ca.*).—The pectorals do not reach the anus; the pelvics, of which the two outer rays are elongated, extend a little beyond the level of the commencement of the first dorsal. The anterior ray of the first dorsal is elongate, and terminates in a filament. It has a total length of 8.5 cm., but has evidently been at some time broken off at about half its present length, and the distal portion appears to be a new growth, and therefore probably shorter than normal. The second ray is a stout arthroneme, 7.8 cm. long; the succeeding rays are shorter, the last being minute, so that the outline of the fin, apart from the first ray, is roughly triangular. There is hardly an interspace between the two dorsal fins, their membrane being continuous. There is a distinct indentation of the outline of the second dorsal, due to inequality in the length of its rays. Thus the anterior rays are 5.3 cm. in height, but at a point somewhat behind the middle (of the fin) the height of the rays decreases to 4.5 cm., increasing again to 5.3 at the thirty-first ray. The rays posterior to this decrease very rapidly, so that the end of the fin is oblique in outline. The incurvature of the dorsal margin is much better marked in this specimen than is shown in fig. 3, Pl. xxxix., which is a sketch of a younger example, in which the condition of the fin-rays leaves some doubt as to the natural outline.

The first anal reaches its full height at about the fourth ray, and decreases towards its posterior extremity in the usual fashion. The seventeenth or last ray of the fin proper is very short but stout, and is separated from the short and very stout ray which is the first of the second anal fin by an interspace of 2.7 cm. The fin membrane, however, is continuous, though much reduced, and from it emerge the tips of three minute and very slender rays. Since the ray, which we have alluded to as the first of the second anal, has all the characters of the anterior ray of a fin, it seems that these three minute interstitial rays must belong to the first anal, if specially to either. As a matter of fact, however, they evidently belong to a primitively continuous fin, and therefore not specially to either of the present (otherwise) separate fins. The reduction of the rays in the central region of the second dorsal is evidently a step in the direction of a sub-division of that fin; and thus in the genus *Mora* we have an interesting illustration of a stage in the evolution of separate fins from the continuous primordial fin or fin-membrane.

The diagrams on pp. 440 and 441 are designed to demonstrate this more forcibly. The figures are intended to show the fins of the adult co-existing with the primordial fin-membrane of the larva.

Figure A represents the lowest term in the Gadoid series in which a distinct caudal fin exists, exemplified by the genus *Brosmius*. That this condition is derived

from a hypothetical ancestral form in which the median fins were entirely continuous round a diphyccereal caudal extremity need hardly be suggested; while such a condition is apparent to this day within the limits of the Gadoid group in such forms as *Fierasfer* and *Ophidion*. The latter, however, can hardly be cited as *retaining* the ancestral condition, since our knowledge of their phylogeny leaves it uncertain that their present conformation (especially in the case of the parasitic *Fierasfer*) may not rather be indicative of a degeneration from a degree of specialization, conforming more nearly to that exhibited by the higher members of the group. There is, perhaps, less occasion for such speculation in the case of the Lycodidæ, and, in any case, all our knowledge of the evolution of the Ichthyopsida points so distinctly to the derivation of the present divided and median fins from an originally continuous organ, that the matter need not be further dwelt upon.

In *Brosmius* (fig. A) it will be noted that the dorsal and anal fin rays are not of equal height throughout, those in the central parts of these fins being so far reduced as to impart a slight incurvation to their outlines, a phenomenon which may be recognised as the inception of a sub-division of the single dorsal and

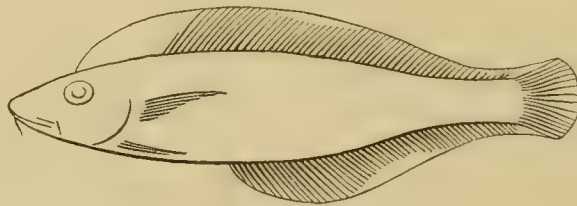


FIG. A.

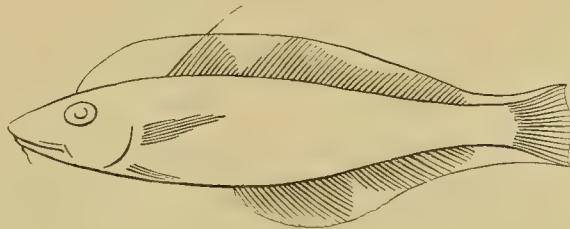
anal into more numerous elements. The condition of *Molva*, *Merluccius*, *Phycis*, *Haloporphyrus*,\* &c., may either come next in the series, or may possibly be parallel to that of *Brosmius*. The former have a short, separate first dorsal and a long second dorsal, which, like the anal, show an incurvation of the outline, practically identical in position with that which we have noted in *Brosmius*. We are acquainted with no form in which the separation of the first dorsal (of *Merluccius*) is foreshadowed by a reduction in the length of the rays comparable to that apparent in the posterior part of the whole fin, but in such a form as *Raniceps* we have perhaps a stage in the degeneration of a short separate first dorsal, and in *Motella* of its specialization to subserve a function in no way connected with natation.† It is possible, therefore, that the present condition of the dorsal in *Brosmius* may have been arrived at by the consummation of such a process of degeneration of a separate first dorsal as appears to be exemplified by *Raniceps*,

\* Cf. figs. 1 and 2, Pl. xxxix.

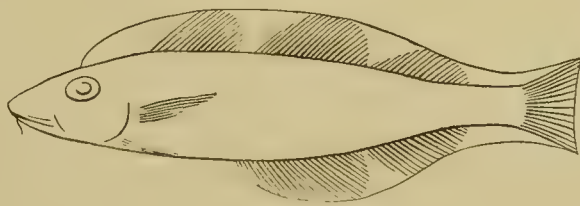
† We allude to the peculiar ciliary function of this fin, but are unable to offer any interpretation of its value.

but the forward extension of the fin in the former genus seems to render this rather unlikely, and to suggest that the fin-stage, in other respects parallel to that of *Merluccius*, &c., diverges so far from the general line of Gadoid evolution as to show no trace of the separation of a short first dorsal.

In *Mora* (or *Halargyreus*) (fig. *B*), we have a distinct advance, since the short first dorsal is already separate, while the outline of the posterior portion shows strong incurvation in its central region, while the anal is only continuous through

FIG. *B*.

the medium of the three very minute rays already alluded to. The transition to *Gadus* (fig. *C*), the highest fin-stage in the series, is very easy, but since the present condition in the fins of that genus seem to indicate a contemporaneous sub-division of dorsal and anal, it is evident that evolution has proceeded in so far

FIG. *C*.

as regards the relations of the different parts of the primordial fin-fold along a line slightly different to that exemplified by *Mora*.

*Teeth*.—Small, slightly curved, cardiform teeth in a band, widest anteriorly on each præmaxilla. A toothless interval between the bands for the reception of an eminence of the symphysis of the mandibles. Teeth on dentaries similar to those of præmaxillæ. Small cardiform teeth in a curved patch on each vomer, slightly more conspicuous than those of jaws. A small patch also on each palatine.

*Scales*.—Present on the body, fins, and head, except on the jaws. Large, oblong, slightly convex anteriorly and posteriorly; not much longer than broad on the sides of the body, but becoming very elongated towards the dorsal and ventral region. There are 90 rows of scales crossing the lateral line, and about 25 scales in a transverse row from the first ray of the second dorsal. About 8 or 9 of these are above, and about 15 or 16 below the lateral line: the condition of the

specimen does not permit of our being more exact. Vaillant remarks that the scales are "assez caduques," but in this and in the specimen figured they could by no means be described as deciduous, though in the third example from the Survey they are almost entirely wanting.

*Lateral line.*—Rising in a very gentle curve in front of the anal region: the posterior portion straight.

*Colour.*—Brownish grey on the back, dull silvery grey on the sides and abdomen. Pectoral fins dark grey, caudal nearly black, pelvic fins colourless. Antero-superior part of first dorsal black, second dorsal edged with very dark grey. Jaws very dark grey. The colours are little affected by preservation in alcohol, except that the sides lose much of their silvery appearance. The mucous membrane of the mouth, and the peritoneum of the body-wall are black.

The colours in Valenciennes' figure ("Hist. Nat. Iles. Canar.," *loc. cit.*) appear to be fanciful. The figure is concisely criticised by Günther ("Cat.," *loc. cit.*) as bad. It has further attracted the attention of Vaillant, who remarks, as also in the case of the figure given by Bonaparte, that it fails to show the great size of the eye as compared with the length of the snout.

The remaining specimens measure, respectively, 30.5 cm. (12 inches) and 22.8 cm. (9 inches). The larger is represented in the sketch (Pl. xxxix., fig. 3).

The small ones differ from the largest specimen only in such details of proportion as may be supposed to vary with the age or size of the individual. Thus the eye is relatively larger, viz. about one-third the length of the head, and its vertical measurement slightly exceeds the width of the interorbital space. The length of the head is about equal to the greatest height of the body, and either measurement is contained only about  $4\frac{1}{2}$  times in the total length without the caudal fin. The somewhat bolder curve of the anterior part of the lateral line is perhaps attributable to similar causes. The statements made in describing the median fins of the largest example apply equally to the smaller ones, except that the anterior ray of the first dorsal is perfect in the latter, and its condition would seem to indicate that the filamentous termination is of no great length in this species. There is, of course, some slight difference in the number of fin rays, the formula for all three specimens being as follows:—D, i. 7-8; D, ii. 43-44; A, i. 16-18 (+ 3); A, ii. 17-20. All three examples have teeth on the palatine bones. The specimen figured agrees in colour with the largest, and has retained its scales in tolerably perfect condition, but the smallest example is almost entirely scaleless, and altogether paler in colour. This is especially noticeable in the distal part of the dorsal fins, where no loss of scales could possibly affect the colouration. It is, no doubt, a pale variety, such as we know from Cuvier and Valenciennes ("Hist. Nat. Poiss.," vi., p. 495), and Lowe (P. Z. S., 1843, p. 91), to exist in *Pomatomus telescopium*. Lowe, indeed, compares the colour of *Mora*

*mediterranea* to that of *Phycis mediterraneus* or of a pale specimen of *P. telescopium*. Both our Irish examples of the last-named species belong evidently to the pale variety, and, except for the purplish ("gorge de pigeon," Valenciennes) hue on the gill cover, are not unlike the darker specimens of Mora, but they are decidedly darker than the smallest example.

*Anatomy.*—On opening the abdominal cavity, the peritoneum is seen to be of an intense opaque black; and the general appearance of the viscera and mesenteries is striking on account of their strong muscular character. (Plate XLIV., A.) On examining the viscera a singular torsion towards the right side is noticeable, so that several organs which usually occupy lateral positions are found in the median plain. The amount of this displacement may be estimated if we suppose that a cross-section of the abdominal cavity represents a circle divided into four compartments, thus: X; and if, after having filled in the viscera of a Gadoid in the normal positions, we turn the subdividing lines on their axis, the extent of one interval, or section of the cross, to the right-hand, imagining the view of the viscera to be from the anterior aspect. The liver, for instance, has two large lobes and one small central lobule. This central lobule, which, in ordinary circumstances, may be seen in the ventral median line, occupies the right side; while the lobe of the right side occupies a dorsal median position, and the lobe of the left side a ventral median position. In the same manner the reproductive organs lie, not side by side, but are above the other, the organ which in ordinary conditions would occupy the right side being in the dorsal position. The strong mesenteries maintain this arrangement. Those in connexion with the reproductive organs form a great sheath passing forwards on the dorsal surface of the stomach, below the dorsal lobe of liver, a branch bending round the left side of the stomach to support the ventral lobe of the liver. The dorsal lobe of liver is the longest, and extends backwards about two-thirds of the abdominal cavity. The stomach is large, with a wall of great muscular thickness, especially on the dorsal aspect. In the specimen under examination, the wall, at its thickest, measured  $1\frac{1}{8}$  inches. The torsion, already referred to, causes the duodenum to spring from the right side. The lumen is narrow, and the intestine, after making two simple bends so as to form a long, much flattened S, passes to the anus. There are twenty pyloric cæca, which bend laterally and posteriorly, encircling, to a certain extent, the ventral lobe of liver.

The swimming bladder exhibits a condition of great interest. A lateral view of the organ, after the removal of its right side, is seen in Plate XLIV., A. It consists of two primary portions: the larger situated partly above and partly posterior to the abdominal cavity; the smaller situated in front of this, partly above the thoracic region, and partly in the region of the head. Those two portions are in communication with one another by means of a canal sunk into

the lower surfaces of the bodies of the 6th, 7th, and 8th vertebræ, but not enveloped by bone. The larger portion is comparatively simple, but wide and capacious, being fully two inches at its broadest. It has towards its anterior end an imperfect horizontal septum, forming an upper and lower compartment. The upper ends blindly, the lower communicates with the canal leading to the anterior portion of the bladder. The lower wall bears two circular rete mirabile below the posterior end of the septum. These are placed one behind the other, and the more anterior one has, immediately above it, a circular opening in the septum, so that, when the bladder is not fully inflated, it can project into the upper horizontal compartment. At the extreme posterior end of this portion of the bladder there is another rete mirabile, formed so as to fit what may be termed the fundus of the bladder. The anterior portion of the bladder is first of all completely divided into two sections, as seen in the figure. The lower section is formed by an extremely delicate membrane, and appears, when looked at from the ventral aspect, to be laid upon the under surface of the firmer and more important section of the bladder. The attachment of the membrane, however, is found to be fibrous and well defined, while the anterior half bears a flattened disc-like rete on its lower surface. The upper section may be said to be naturally divided into two lateral cavities by the anterior portion of the vertebral column, and by the occipital region of the skull. Those cavities communicate with one another at their posterior ends by a passage under the vertebral column. The figure shows only the cavity on the right side of the head, a diagrammatic outline of the bladder as seen from above being given in fig. A'. Each lateral sac is attached by strong fibrous bands posteriorly to the body of the 5th vertebra, and anteriorly to the posterior surface of the pterotic bone.

A median attachment is also secured to the first five vertebræ of the column and to the basi and exoccipital bones.

Each lateral cavity may, therefore, be spoken of as passing forwards, upwards, and outwards from below the level of the fifth vertebra, under both branches of the post-temporal bone, between the supra-scapula and the exoccipital bones, to the posterior surface of the pterotic. The passage leading from the cavity of one side to that of the other has situated in it three circular rete mirabile, and is, in the specimen figured, of sufficient size to admit the little finger. Into this passage the canal leading from the larger or posterior portion of the bladder opens. At no part of the air-bladder is there any pneumatic duct in connection with the alimentary tract.

The kidneys remain to be mentioned. They are situated in the normal position, immediately superior to the swimming-bladder, but as in other deep-sea fishes are much prolonged. There are two distinct head-kidneys which could not be shown in the figure, as it was necessary to dissect the right one away, along with

the post-temporal bone, in order to show the head portion of the air-bladder. In the body-region, the kidneys become flattened and thin, and unite in a more or less indefinite manner when they are about the level of the posterior end of the abdominal cavity. At the extreme posterior end of the bladder this single organ is reflected downwards to form a thickened mass, roughly pyramidal in shape. This may be seen in the figure.

We have not examined the skeletal anatomy of any of our specimens since we know from Günther's observations ("Cat." *loc. cit.*) that the species presents no points of special interest in this respect.

Vaillant has described and figured the Sagitta.

### Genus *Merluccius*, Cuvier.

#### *Merluccius vulgaris*, Fleming. The Hake. (Deep-sea.)

- M. vulgaris*, . . . . . GOODE, "Proc. U. S. Nat. Mus.," iii. 1881, pp. 337, 476.  
 ,, ,, . . . . . GOODE, "Bull. Mus. Comp. Zool.," x., 1883, p. 207.  
 ,, ,, . . . . . VAILLANT, "Exp. Sci. Trav. Talism., Poiss.," p. 300.  
 ,, ,, . . . . . HOLT, "Sci. Proc. R. Dub. Soc.," vii., p. 219.

Hake were taken during the Survey at 115 and 220 fathoms off the coast of Kerry, and at 154 fathoms off the coast of Mayo. The species also occurred abundantly in shallow water. On the New England coast, hake have been taken at a maximum depth of 487 fathoms, spawning examples being secured at depths between the last-mentioned and 250 fathoms (Goode). Vaillant records the species from a maximum depth of 346 fathoms off the N.W. coast of Africa.

### Genus *Phycis*, Cuvier.

#### *Phycis blennioides*, Brünnér. The Fork-beard. (Deep-sea.)

- P. blennioides*, . . . . . STROM, "Norst. Vid. Selsk. Skr.," 1881, p. 76, 1884, p. 35.  
 ,, ,, . . . . . COLLETT, "Nyt. Mag. f. Naturvid.," 1884, p. 83.  
 ,, ,, . . . . . GÜNTHER, "Ann. Mag. Nat. Hist.," iv., 1889, p. 417.  
 ,, ,, . . . . . SCHARFF, "Proc. Roy. Ir. Acad.," 3rd S., i., 1891, p. 457.  
 ,, ,, . . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," pp. 122, 219.

Fork-beards were taken during the Survey at 154, 220, and 375 to 500 fathoms off the coast of Kerry; and a young example occurred at 26 fathoms in

the Kenmare River. A single specimen was taken off the S.W. coast by the "Flying Fox" at 150 fathoms. Others were secured by the "Lord Bandon" in the same locality, but the depth is not stated. On the Norwegian coast the species has been recorded from a maximum depth of 200 fathoms. It occurs regularly in the comparatively deep part of the North Sea (about 40 to 50 fathoms) to the northward of the Great Fisher Bank, and has occasionally been taken at many points on the British coast, although no records of the depths are available. In addition to the instances cited above, only a few specimens have been recorded from Irish waters. The species extends along the Atlantic coasts to the Mediterranean, where it is common, and, apparently, littoral in distribution. On our own coasts it certainly appears to be most usually met with in rather deep water, and is, probably, by no means uncommon below the 100-fathoms line of the western slope.

**Phycis Aldrichii**, Bourne. (Deep-sea.)

*P. Aldrichii*, . . . . . BOURNE, "Journ. M.B. Assoc.," N.S., i., 1890, p. 310.

The only known examples of this species were obtained by Mr. Bourne at 200 fathoms off the S.W. coast of Ireland.

Genus **Haloporphyrus**, Günther.

Body elongate, covered with small scales. A separate caudal; two dorsal fins and one anal, the first dorsal with four rays; ventrals narrow, composed of six rays. Jaws with bands of villiform teeth; vomerine teeth in a small roundish patch; none on the palatine bones. Chin with a barbel. Branchiostegals, seven.

**Haloporphyrus eques**, Günther. (Deep-sea.)

(Pl. xxxix., figs. 1 and 2.)

*H. eques*, . . . . . GÜNTHER, "Chall. Rep.," xxii., p. 91.  
 ,, . . . . . BOURNE, "Journ. M.B. Assoc.," N.S., i., p. 311.  
 ,, . . . . . SCHARFF, "Proc. Roy. Ir. Acad.," 3rd S., i., p. 459.  
 ,, . . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., p. 122.

DIAGNOSIS OF SPECIES.—(D, i. 4; D, ii. 56–62; A. 49–54; Pelv. 7; L. lat. 180; Cæc. pyl. 10–11.)—The length of the head equal to, or rather less than, the

distance between the origin of the pelvis and the anal, and rather less than one-fourth of the total length (without caudal). The eye longer than the snout by one-third the length of the head, and nearly twice the width of the inter-orbital space. Snout obtuse, with an undulated series of pores in the pre-orbital region, running towards the extremity of the snout. Barbel about half the length of the eye. Angle of the gape opposite or a little in front of the centre of the eye. Caudal peduncle very slender, its height being about two-fifths of the distance between the dorsal and the caudal, or a little more than one-fourth of the length of the eye. Fifteen or sixteen longitudinal series of scales between the first dorsal and the lateral line. The first long dorsal ray compressed, moderately strong, extending back beyond the centre, frequently to the posterior fourth, of the second dorsal fin. Of the second dorsal and anal, the outline of the latter is especially incurved in its central region. Caudal rounded, its external rays extending some distance along the peduncle. Pectoral, as long as the head without the snout. Pelvic, with the two outer rays elongated and filamentous, equal to the length of the pectoral, and united along their proximal half.

*Colour*.—Brownish or dull silvery grey, darkest on the dorsum; fins dark grey, those of the median series nearly black on the marginal parts.\* Cavities of the mouth, gills, and abdomen, black.

*Size*.—Not known to exceed a total length of 13 inches.

The species has been excellently described and figured by its discoverer; and our own description, which differs in no important respect from that given by Dr. Günther, is inserted only in accordance with the plan of the present Paper.

The larger specimen, shown in fig. 2, has the long dorsal ray broken, the slender extremity representing apparently a growth which has taken place subsequently to the original injury. The figure is taken from the preserved condition, which accounts for the shrunken appearance of the skin over the muscous cavities of the head.

The smaller specimen (fig. 1), has the first ray complete, but extending only to about the centre of the second dorsal fin. The barbel is not shown, being turned back in the gular groove. Apart from the mere obvious developmental differences, it will be noted that the anus, in the larger, is comparatively more remote from the anal fin than in the smaller example. A similar condition is shown in the specimen figured by Günther (*op. cit.*, pl. xviii., fig. *B*). This decrease of measurement between the anus and the pelvic fins may probably

\* According to Günther (*loc. cit.*), "specimens of a much lighter colour (probably albinos) are not scarce."

occur with the growth of the individual, as is the case in some species of *Macrurus*.

*Locality and Distribution.*—The Survey examples are five in number, and were all taken at 500 fathoms, 54 miles off Achill Head. So far as is at present known, the species is confined to the deep water in the neighbourhood of the British Isles. It appears to be abundant in the Faroë Channel, where the first specimens were taken by the “Knight Errant,” at 530 fathoms, in 1880 (Günther). On the Irish coast the first example was secured by the “Flying Falcon,” at 750 fathoms, in 1881 (Scharff); while another was taken by the “Research” in the following year (Bourne).

Genus *Molva*, Nilss.

*Molva vulgaris*, Fleming. The Ling. (Deep-sea.)

- M. vulgaris*, . . . . . COLLETT, “Nyt. Mag. f. Naturvid,” 1884, p. 84.  
 „ . . . . . LILLJEBORG, “Sverig. o. Norg. Fisk,” p. 131.  
 „ . . . . . HOLT, “Sci. Proc. R. Dub. Soc.,” vii., pp. 122,  
 219, 441.

Specimens were taken during the Survey at 127 and 154 fathoms off the coast of Mayo, as well as in littoral waters. Ling are constantly taken on the Norwegian coast at depths exceeding 100 fathoms, the largest, according to Lilljeborg, coming from 80 to 150 fathoms, while Collett remarks that young examples are rarely taken at less than 100 fathoms. On our own coast, as has been pointed out by one of us,\* the young are not infrequent in quite shallow water.

Off the Faroë Islands ling are regularly taken on the long lines at depths exceeding 100 fathoms; but there is difficulty in obtaining from the fishermen, who are our informants, exact information as to the maximum depth at which the species has been caught.

\* Holt, *supra*, iv. 91, p. 96.

Genus **Motella**, Cuvier.**Motella cimbria**, Linnæus. (Deep-sea.)

*Onus cimbricus*, . . . . . GOODE and BEAU, "Proc. U. S. Nat. Mus.," iii.,  
1881, p. 476; "Bull. Mus. Comp. Zool.," x.,  
1883, p. 207.

*M. cimbria*, . . . . . SCHARFF, "Irish Naturalist," 1893, p. 176.

This rockling was not known from Irish waters at the time of the Survey, but, in suggesting it as the possible parent of a *Motella*-like ovum and larva, doubts were expressed by one of us\* as to how far its absence from the Irish list could, in the existing stage of our knowledge of the Irish fish-fauna, be held to invalidate the suggestion. The parentage of the ovum remains in doubt, but the adult has since been added to the Irish list by Dr. Scharff. It is only known in the old hemisphere as a littoral form, but has been recorded from the American coast at 178 fathoms.

**Motella tricirrata**, Bloch. (Deep-sea.)

*M. tricirrata*, . . . . . VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 285.

The three-bearded rockling was taken in the French dredging expedition at a maximum depth of 346 fathoms off the N.W. coast of Africa. "Mackerel-midges," apparently belonging to this species, were frequently taken at the surface during the Survey, but no adult forms were met with at any depth.

Genus **Brosmius**, Cuvier.**Brosmius brosme**, Müller. The Tusk or Torsk. (Deep-sea.)

*B. brosme*, . . . . . GÜNTHER, "Proc. Roy. Soc. Edin.," 1882, p. 680.

„ . . . . . LILLJEBORG, "Sver. o. Norg. Fisk.," ii., p. 202.

„ . . . . . SMITT, "Hist. Skand. Fish.," ed. 2, p. 562.

Several tusk were taken during the Survey at 250 fathoms off the coast of Mayo. The species is very little known in Irish waters, although it appears to occur regularly off Dingle Bay. Mr. Green, who is our informant in this respect, tells us that the fish is known in that district as the "Cat-ling." It is evident that the fishes alluded to by Day as taken "far out at sea off the Galway coast" belong to this species, and not, as was supposed, to *Anarrhichas lupus*.

\* Holt, *supra*, iv., 1891, p. 96.

Günther records the capture of a tusk at 530 fathoms in the Faroë Channel. On the coast of Norway it is said by Smitt to be common at 100 to 200 fathoms. Off the coasts of Iceland and the Faroë Islands it is taken at depths of over 100 fathoms, and also, according to fishermen, in quite shallow water.

Fam.—**MACRURIDÆ.**

Genus **Macrurus**, Günther.

Head generally with large muciferous cavities. Snout frequently projecting beyond mouth, which may be inferior, or sub-terminal and lateral. Jaws armed with small teeth: no teeth on the palate. A barbel on the mandibular symphysis. Scales cycloid or ctenoid. The second dorsal always less developed than anal, its rays frequently rudimentary in front or throughout.

Four gills. The slit between gill cover and first branchial arch partly obluded by a broad fold of the membrane of gill cavity so as to be much narrower than the slits between branchial arches. No pseudo-branchiæ. No scaleless fossa on the nape.

For a fuller discussion of the characters of the genus we would refer readers to the "Challenger" Memoir (pp. 122-124), drawing especial attention to Dr. Günther's remarks on the development of the adult characters of the scales, and the changes in proportions. Twenty-nine specimens of Macruri were trawled during the Survey, belonging to four species.

Günther, in his systematic arrangement of the genus, divides it first of all into three sections, which are again divided into subgenera, and in dealing with our material we propose to follow this arrangement, quoting the characters of the subgenera represented, viz.: *Cælorhynchus*, *Macrurus*, *Coryphænoides*, and *Malacocephalus*. Of these the first three belong to Section I., and the last to Section III. We may add that, for general convenience, we have, in our diagnoses of species, adhered as closely as possible to Günther's descriptions, only altering them in details whereon additional information is furnished by our specimens.

SECTION I.—Teeth in villiform bands above and below; that of the lower jaw always broadest near the symphysis, and sometimes tapering into a series on the side of the jaw.

A. Scales distinctly imbricate, without enlarged dorsal scales.

1. Scales spinigerous.

- a. Mouth entirely on the lower side of the head, a longitudinal ridge dividing the infraorbital region into a vertical and sub-horizontal portion. Dorsal spine smooth.

Sub-genus *Cælorhynchus*.*Macrurus cælorhynchus*, Risso. (Deep-sea.)

(Pl. XL, figs. 2 and 2a).

- Lepidoleprus cælorhynchus*, . . . RISSO, "Ichth. Nice," p. 200.  
*Macrourus cælorhynchus*, . . . BONAP., "Faun. Ital. Pesc." (pl. xxx., *Macrourus mysticetus*).  
 " " . . . COSTA, "Faun. Nap.," *Gen. macr.*, p. 2.  
 " " . . . CANESTRINI, "Arch. Zool.," ii., p. 374.  
 " " . . . JOHNSON, "Ann. Mag. Nat. Hist.," 1862, p. 169.  
*Macrurus cælorhynchus*, . . . GÜNTHER, "Chall.," vol. xxii., p. 128.  
 " " . . . GÜNTHER, "Ann. Mag. Nat. Hist.," 1889, p. 417.  
 " " . . . VAILLANT, "Exp. Sci. Trav. Talism.," Poiss., p. 247.  
 " " . . . BOURNE, "Jour. M.B.A.," N.S., vol. i., p. 311.  
 " " . . . SCHARFF, "Proc. R.I. Acad.," 3rd S., vol. i., p. 459.  
 " " . . . HOLT, "Proc. Roy. Dub. Soc.," vol. vii., p. 122.  
*Macrurus atlanticus*, . . . LOWE, "Proc. Zool. Soc. Lond., 1839," p. 88.  
 " " . . . GÜNTHER, "Cat. Fish. Brit. Mus.," vol. iv., p. 392.

DIAGNOSIS OF SPECIES. (D. 9–10\* ; P. 18–20 ; Pelv. 7.)—Snout moderately produced, angular in front, a little shorter than, or equal to, the eye, the diameter of which equals three times the distance from tip of snout to base of first dorsal fin-ray. The interorbital space varies from  $1\frac{1}{2}$  diameters of eye in specimens of 24 cm. to  $1\frac{2}{3}$  in specimens of 12 cm. Scales of moderate size, covered with minute spines, giving a granular appearance to their surface. The spines are not numerous, and are arranged in three imperfect rows, the central being the longest.

There are five or six scales in a transverse row between the first dorsal fin and the lateral line. Dorsal spine smooth. The distance between the vent and isthmus becomes slightly greater with the growth of the individual. In small specimens the vent is situated on a level with the posterior spine of first dorsal fin. Outer pelvic ray produced into a short filament. Muciferous cavities exist in the snout and interorbital region, above the operculum, and round the eye. There is a scaleless oval depression between the pelvic fins, black in colour.

*Colours*.—Dull silvery grey on the sides and back ; black on the abdomen in the region of the pelvic fins.

*Size*.—The species does not appear to reach a large size. An example measuring 12 inches is mentioned by Günther. In the above diagnosis this specimen, and the smallest of our own,  $4\frac{3}{4}$  inches long, must be considered in interpreting the terms "large" and "small."

\* The short anterior spine, usually hidden by the skin, is not counted.

*Locality and Distribution.*—Nine specimens, from 12·1 to 24·7 cm. ( $4\frac{3}{4}$  to  $9\frac{3}{4}$  inches) long, were trawled at 144 and 220 fathoms, 40 miles off Achill Head, on the 4th July, 1890.

The species had already been taken on three occasions off the west coast of Ireland, viz. during the expeditions of the “Flying Falcon,” “Flying Fox,” and “Research.” It was previously known from the Mediterranean and off Madeira, and was taken during the expedition of the “Talisman” and “Travailleur” at various points between the Bay of Biscay and the Azores. A young specimen taken from the stomach of a cod-fish near Bergen is believed by Collett to belong to this species,\* perhaps the commonest of the European *Macruri*.

It is one of the few species of *Macrurus* that has been recorded from above the 100-fathoms line, having been captured on one occasion during the French expedition at 88 fathoms; 345 fathoms, the depth at which it was taken by the “Flying Falcon,” represents the opposite extreme of its vertical range, so far as it is known to us.

*DESCRIPTION OF SPECIMENS.*—For the comparison of specimens of different sizes we have chosen a series of five examples, ranging from 12·1 cm. to 23·7 cm. in total length. These we shall speak of as A, B, C, D, and E.

The following is a Table of dimensions of these specimens.

	A.	B.	C.	D.	E.
	<i>cm.</i>	<i>cm.</i>	<i>cm.</i>	<i>cm.</i>	<i>cm.</i>
Total length, . . . . .	23·7	16·0	14·6	13·4	12·1
Length of head, . . . . .	5·3	3·2	3·0	3·1	2·5
„ snout, . . . . .	1·9	1·2	1·0	·9	·8
Width of „ . . . . .	2·1	1·3	1·3	1·2	1·1
„ inter-orbital space, . . . . .	1·3	·7	·7	·7	·6
„ head, . . . . .	3·0	1·7	1·6	1·5	1·2
Greatest height of body, . . . . .	3·3	1·8	1·9	1·8	1·4
„ width „ . . . . .	2·2	1·1	1·1	1·2	1·0
Tip of snout to mouth, . . . . .	2·0	1·1	1·1	1·0	·9
„ „ 1st dorsal fin, . . . . .	6·1	3·9	3·4	3·4	2·8
„ „ 2nd „ . . . . .	8·9	5·5	5·0	4·9	4·0
„ „ pelvic fin, . . . . .	5·9	3·1	3·2	3·1	2·8
Greatest diameter of eye, . . . . .	1·9	1·2	1·1	1·2	1·1
Least „ „ . . . . .	1·5	·8	·8	·8	·7
Vent to isthmus, . . . . .	3·3	2·0	2·0	1·9	1·7

From the above Table it will be seen that the increase of length of the species

\* “Norges Fisk,” p. 129.

is accompanied by a steady increase in the dimensions of the various parts, and that in no particular does any sudden proportional variation take place. Only one exception appears in column D (13·4 cm.) where the greatest diameter of eye shows an increased measurement when compared with the larger specimen C (14·6 cm.), and the same measurement as the much larger specimen B (16 cm.). In this particular specimen, however, the membrane of the eye, and the muciferous cavities of the head, show very decided evidence of shrinkage, and we are inclined to consider that, if indeed the increased measurement is not due to an individual peculiarity, it may be explained by the shrinkage of the outer membrane.

*Fins.*—In Günther's description of this species\* no variation is shown in the fin-ray formula except with regard to the anal fin, which, on account of the uncertainty which often may occur as to whether or not the entire caudal termination is present, can readily be understood, especially in a species where most of the examples procured have been of small size.

In seven specimens examined by us with regard to the fins, a certain variation takes place, and we have therefore shown it in our fin-ray formula at the commencement of this description. The details are as follows:—

Specimen,	23·7 cm.	1st Dorsal,	10	Pectoral,	18	Pelvic,	7
„	16·0	„ „	10	„	19 ?	„	7
„	16·0	„ „	9	„	18 ?	„	7
„	14·6	„ „	9	„	20	„	7
„	13·4	„ „	10	„	18	„	7
„	incomplete	„ „	10	„	—	„	7
„	12·1	„ „	9	„	20	„	7

Johnson (*loc. cit.*), describing some specimens taken at Madeira, gives the number of fin-rays in the second dorsal as 98, and in the anal 110. His largest specimen was  $13\frac{1}{2}$  inches in length, or 4 inches longer than the largest specimen in the above Table. Günther gives 75–86 as the numbers applicable to the second dorsal.

*Abdominal Viscera.*—On opening the abdominal cavity, the oval depression is seen to be the inferior surface of a gland-like body lying embedded in the abdominal wall. It is flask-shaped, and perfectly black in colour. The neck of the flask forms a canal which runs directly backwards along the inferior surface of the abdomen, in the middle line, until it comes in contact with the opening of the rectum, to which it has a fibrous attachment. A probe can readily be passed along this canal from the gland-like body, but fails to find free access to the rectum. In some specimens of *M. laevis*, trawled at night, a highly luminous fluid was observed to issue from the vent, or from its immediate neighbourhood. No

\* “Challenger” Reports, vol. xxii., p. 128.

opportunity occurred of examining by night any other species of macruri during the Survey; but since *M. laevis* also possesses a black, scaleless depression between the pelvic fins, and shows some traces of an internal arrangement similar to that met with in the species before us, it seems possible that this gland-like body may be in some way functional for purposes of illumination.

The peritoneum is thickly speckled with black pigment, but the mouth is white.

The rectum comes almost perpendicularly downwards towards the vent, and the reproductive organs which are situated at the posterior extremity of the abdominal cavity send their ducts forwards and downwards. On the left side a long lobe of liver extends the entire length of the abdominal cavity, and bends into a median position posteriorly. The right lobe of the liver is insignificant, but on this side of the body a fold of the intestine passes backwards. The pyloric coeca are numerous, but not to the same extent as in *M. laevis*. The stomach is large and rounded, the duodenum springing from the centre of the inferior surface.

The viscera completely filled the cavities of the specimens examined; and in an example of fair size (23.7 cm.) which had the appearance of being a mature male, the testes were joined together posteriorly so as to form a single-forked organ.

The air-bladder is attached laterally to the extremities of the transverse processes of the dorsal vertebræ. On opening it, along this lateral line of attachment, the cavity is seen to project to a certain extent backwards beyond the abdominal cavity proper, to the level of the fifth anal fin-ray. It is wide and capacious in extent. Anteriorly, below the dorsal fin, it becomes constricted, and ends behind the head in a somewhat broad point. A convoluted rete lies on the inner inferior surface near the anterior end. The superior membrane of the bladder is imperfect, so that a circular space occurs at a point corresponding with the position of a central muscular opening described in *M. laevis* (p. 477). A portion of the kidney can be seen passing immediately above this opening. There are two head-kidneys continuous with a single body organ, as described below in the case of *M. laevis*.

*Skeleton*.—The skull is figured by Costa (*op. cit.*, Pl. xxxix.)

#### SECTION I. A.—SUB-SECTION 1 (*supra*).

*c.* Mouth wide and lateral; dorsal spine serrated.

Sub-genus *Coryphænoides*.*Macrurus rupestris*, Gunner. (Deep-sea.)

(Pl. XLIII., fig. 2; and fig. in text.)

- Berg Lax*, . . . . . STRÖM, "Sond.," i., p. 267.  
*Coryphænoides rupestris*, . . GÜNNER, "Trondhj. Selsk. Skrift.," vol. iii., p. 50,  
 tab. iii., fig. 1.  
 " " . . COLLETT, "Forhandl. Vidensk. Selsk. Christ.," 1880,  
 p. 70.  
 " " . . LILLJEBORG, "Sverig. och. Norg. Fisk.," p. 259.  
 " " . . DAY, "Fish. Gt. Brit.," vol. i., p. 335, pl. xciii.  
*Macrurus rupestris*, . . . GÜNTHER, "Challenger," vol. xxii., p. 138.  
 " " . . . HOLT, "Proc. Roy. Dub. Soc.," vol. vii., p. 122.  
*Macrurus norvegicus*, . . . NILSSON, "Skand. Faun. Fisk.," p. 600.  
*Coryphænoides norvegicus*, . . GÜNTHER, "Cat. Fish. Brit. Mus.," vol. iv., p. 396.  
*Macrourus Stroemii*, . . . REINHARDT, "K. dansk. Vidensk. Selsk. Afhandl.,"  
 vol. viii., p. 129.

*Locality and Distribution.*—Four examples, varying in length from 67·2 to 96·4 cm. ( $26\frac{1}{2}$  to 38 inches), were trawled at a depth of 500 fathoms, 54 miles off Achill Head, Co. Mayo, on the 10th July, 1890.

The species was thus for the first time added to the British Fauna, but having previously been taken in the deep channel between the Faroë and Shetland Islands, it cannot be said to be new to British waters. So far as the horizontal range is ascertained, the species appears to be confined to the North Atlantic, occurring in the waters of both hemispheres.

Thus, on the eastern side, it has been recorded from Finmark and the North Cape (Nilsson), from various parts of the Scandinavian coast (Collett and Lilljeborg), and from the Faroë channel (Günther). On the western side it has been taken off Greenland (Reinhardt), and off the N.E. coast of the United States (Goode and Beau).\* The species does not appear in the list of deep-sea forms taken in the "Talisman" and "Travailleur" expeditions; and since the latter vessels worked as far north as the Bay of Biscay it seems unlikely that the species extends much further south, on the European side, than the British Islands, but must rather be considered as a northern form.

\* "Bull. Mus. Comp. Zool.," x., 1883, p. 197.

The vertical range is summarised by Lilljeborg, as from 100 to over 500 fathoms, probably with approximate correctness, though we know of no exact record of the occurrence of the fish at less than 200 fathoms. Günther's Faroë examples were taken at depths ranging from 200 to 500 fathoms, and the United States specimen at 524 fathoms, which seems to be the maximum recorded depth.

DIAGNOSIS OF SPECIES. (D. 10-12; P. 17-21; Pelv. 7-8).—Head short, rather compressed; snout short, obliquely truncated in front; cleft of mouth wide, lateral, extending to beyond the centre of the eye in adults, but barely reaching the front of the eye in very young examples. Præmaxilla not much shorter than maxilla. Teeth in villiform bands in both jaws: barbel very short. Inter-orbital space convex, its width greater than diameter of eye, which is equal or nearly equal to length of snout, and is about one-fourth the length of head. Scales rough; spinelets directed backwards, present on whole of exposed surface of scales, and longest on scales of ventral aspect of abdomen. Six to nine scales in a transverse series between first dorsal fin and lateral line.\* Head entirely covered with small scales. Anterior dorsal spine armed with numerous small closely set serrations, usually absent in large examples from the proximal region of spine; outer pelvic ray produced into a longish filament. Distance between vent and isthmus about two-thirds to four-fifths of the length of the head.

*Colouration*.—Brownish on the back, dull silvery grey on the sides and belly. Branchiostegal membrane and mouth black. Fins dark grey or black.

*Size*.—We can find no record of an example exceeding the length of the largest of our series, viz. 96·4 cm. or 38 inches. Günther mentions specimens nearly three feet long, received from Sognefjord. The species appears to reach a larger size than any of its European congeners.

DESCRIPTION OF SPECIMENS.—Examination of the four specimens reveals a certain divergence of characters, which at first sight made us think it possible that we might be dealing with members of more than one species. On comparing them, however, with examples in the British Museum from other localities, it becomes evident that such differences as the Irish examples exhibit amongst themselves cannot be regarded as of specific value, but can be sufficiently dealt with by imparting a little more elasticity to the general diagnosis of the species. It will be noticed that, especially with regard to proportions, the diagnosis which we have given on the preceding page permits of a degree of variation somewhat in excess of that defined by Günther in his description of the species in the "Challenger" Memoir. On a casual inspection our specimens arrange themselves into two groups, the most readily noticeable distinction being the greater or less degree of

\* This statement is made upon the authority of Lilljeborg (*op. cit.*, p. 259), but seven or eight seems to be the usual number.

obliquity in the anterior profile; in two, including that shown in Pl. XLIII., fig. 2, which appear to conform most closely to the ordinary type in the character alluded to, the anterior profile is only moderately oblique, and the snout is consequently somewhat obtuse, whereas in the two remaining examples it is somewhat sharp.

There exist, moreover, other differences, which, were they associated with those already mentioned, would present some difficulty to the systematist. It happens, however, that they occur independently, since specimens which in some character conform to one type, depart from it signally in another.

To illustrate this more fully we have selected two examples for detailed description and comparison: they may be termed respectively, A and B, the former conforming in the contour of the snout to the normal condition illustrated by the specimen shown in figure 2.

#### *Dimensions.*

	A.	B.
Total length, . . . . .	74·5 cm.	93·90 cm.
Length of head, . . . . .	15·9	13·80
„ snout, . . . . .	3·8	3·45
„ eye, . . . . .	3·3	3·45
„ præmaxilla, . . . . .	4·9	4·50
„ barbel, . . . . .	1·0	1·05
Greatest height of body, . . . . .	12·6	11·60
„ „ of head, . . . . .	11·2	9·60
„ width of „ . . . . .	7·2	6·60
Width of interorbital space, . . . . .	5·6	4·55
Distance from isthmus to vent, . . . . .	8·7	11·40
Tip of snout to first dorsal fin, . . . . .	15·9	14·30
„ „ to vent, . . . . .	17·6	19·20

*Proportions.*—Owing to the frequency with which the *Macruri* lose some portion of their caudal extremities, the total length of a specimen, as it comes to hand, is not always a safe unit to use in the computation of proportions, and it happens that example A is certainly short of its natural length by several centimetres. As appears to be usual, fin-rays, presumably from the anal fin, have made their appearance on the mutilated end, simulating a caudal fin, much in the manner illustrated by Günther (“Chall.,” vol. xxii., pl. xxx., fig. 2*a*) in the case of *M. serrulatus*.

The distance between the snout and the vent may also be distrusted, owing, as we have seen when dealing with *M. æqualis*, to an irregularity in the position of the vent which manifests itself in several species of *Macrurus*. But when, as in the case before us, the relations of the vent to the commencement of the anal fin are about the same, the pre-anal length may be considered of some importance.

By adopting it as the unit it becomes at once apparent that the head is relatively longer, and the body relatively higher, in A than in B; to express it more exactly, the length of the head is in A about eight-tenths, in B seven-tenths, and the greatest height of the body (situate in both examples as the anterior ray of the first dorsal) is in A seven-tenths, and in B six-tenths of the length of the fish in front of the vent. B is, in fact, judged by this standard, a more elongate example than A; but if we use the length of the head as the unit, we find the height of the body relatively greatest in B. Such a condition is the reverse of what might be expected from the analogy of other species (since B is considerably the smaller of the two), and therefore tends to demonstrate the importance of the pre-anal length in this particular case. The position of the first dorsal, which is in A opposite to, and in B a little behind, the end of the head, may also be taken as evidence to the same effect.

Turning to the proportions of the head, we find the eye relatively largest in B, viz. it is contained 4 times in the length of the head; in A nearly  $4\frac{3}{4}$  times. The relative dimensions of the snout and eye are also somewhat different, since in B these structures are of equal length, whereas in A the former is slightly the longer. Relatively to the height, the head is somewhat the wider in A. The distance between the vent and the isthmus, a dimension which has been found of use in the specific diagnosis of many Macruri, is naturally dependent on the degree of elongation of the body, or on the developmental migration of the vent, when such occurs. Accordingly in A the distance is not quite equal to two-thirds of the length of the head, while in B it is more than four-fifths of the same dimension. So far as proportions are concerned, the specimen figured agrees very nearly with B.

The net result of the comparison of dimensions appears to be that our specimens show a greater and a lesser type of elongation, or a microcephalous and a macrocephalous condition, of which the latter appears to be the more in accordance with the normal condition (so far as that can be gathered from the literature of the subject). The former type, however, is here associated with what seems to be the more normal proportions of the head, *inter se*.

*Conformation.*—In A the snout is comparatively blunt, and the anterior profile only slightly oblique, as in the specimen shown in figure 2. The dorsal profile rises in an unbroken curve to the commencement of the first dorsal fin. It is smooth, and destitute of depressions, except immediately behind the snout, where a moderate-sized sulcus occurs, as in figure 2, above the nostrils on either side. The condition, in fact, bears a strong resemblance to that met with in figure 2, the chief difference being that the inter-orbital space is slightly less convex in the specimen figured. In B the anterior profile is much more oblique, forming an angle of about  $45^\circ$ , with a vertical from the tip of the snout. The dorsal

profile is less expanded, a strong sulcus existing in the middle line, somewhat behind the level of the centre of the eye. The muciferous cavities of the head are everywhere very strongly marked; and it is possible that the difference in profile which this (and also the smallest example of our series) presents to the other specimens may be to some extent due to the collapse of these structures from the effects of the preserving fluid, though it cannot be attributed to this cause alone. The shape of the head is otherwise very similar in all three examples, the distinct, but blunt, sub-orbital ridge being about equally well marked in B. In B, however, the margin of the pre-operculum is rather more angular than in the others. Day's figure, which represents a specimen only 6 inches long, shows the margin of this bone exposed, and strongly serrated. In all our examples the whole of the structure is covered with scales, so that the serrations, if they exist, are thereby masked, and, from an examination of Day's specimen (in the British Museum), we think it probable that the absence of scales is due to injury in the net, and not a natural condition.

In their remaining characters the two specimens, A and B, show so little difference, that, except in a few trifling details, one description will serve for both.

*Teeth and Jaws.*—The teeth, arranged in bands in either jaw, are villiform; and in the upper jaw those of the outer series are a little larger than the rest, especially near the centre of the gape, where two or three rather large teeth occur on either side. There is a toothless interspace in the centre. The angle of the jaw is behind the centre of the eye (and more noticeably so in the specimen figured), and the scaleless oral groove extends beyond the hinder margin of the orbit.

*Scales.*—Relatively rather large, beset over the whole of the exposed surface by rather long but not very stout spinelets; the central spinelets noticeably stronger than the rest. The scales on the sides of the body are rather broader than long; thus a scale from near the lateral line at the level of the commencement of the second dorsal fin measures in A .8 cm. long by 1 cm. broad, and in B .8 cm. by 1.1 cm. There are eight scales in a transverse row from the base of the anterior dorsal ray to the lateral line in A and B, and either eight or nine in the specimen figured. The presence of the spinelets gives a velvety, or almost a furry, appearance to the skin of large examples such as A or B; but small specimens, such as those taken by the "Porcupine" and "Knight Errant," look very much smoother, and in fact have much the same appearance as specimens of *M. lævis*, so far as the skin is concerned.

*Fins.*—There are eleven rays in the first dorsal of both specimens, in addition to the very short anterior spine (not counted in the fin-ray formula), which in A is completely buried under the skin. The anterior ray is imperfect in all our

specimens, so that its exact length is doubtful. In B what remains of it is equal in length to the post-orbital part of the skull, but only the distal third is serrated. The serrations in all our specimens are confined to the distal portion, though in young examples they extend to the base of the ray. The upper part of the fin is black.

The pectoral fins have nineteen rays, with the exception of the left pectoral of B, which has only seventeen. The pelvic fins have eight rays, the outer produced into a filament, but in the two specimens there is only one perfect filament (in the left fin of B); it measures 8.6 cm. A furrow is observable in the dorsum at about twice the length of the head from the snout (in B, rather less in A), and probably represents the commencement of the second dorsal fin, but no rays are observable for some distance back. There is no membrane to this fin. The rays of the anal fin are rather long and slender; the membrane extends to the tips. The false caudal fin of specimen A has already been alluded to.

*Lateral line.*—Parallel to the dorsum in the posterior region. Anteriorly, from a point about two head-lengths from the snout, it rises in a very gentle curve, the

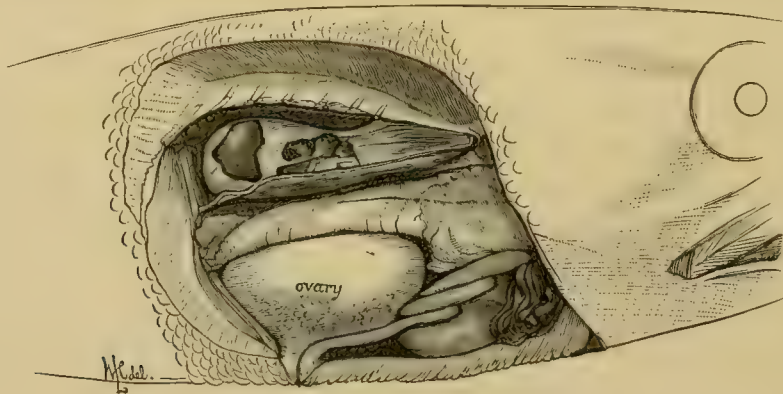


FIG. D.

summit of the curve being about opposite the anus in A, and the centre of the first dorsal fin in B, and in the specimen figured. The curve is not the same on both sides of B.

*Colours.*—The black of the branchiostegal membrane, distal part of the first dorsal, and of the pectoral, pelvic, and anal fins, is a brownish black, as opposed to the bluish black met with in *M. cequalis*.

*Visceral Anatomy.*—On opening the abdominal cavity the peritoneum is seen to be thickly speckled with black pigment-cells giving a grey colour to the membrane. The specimen figured was found to be a nearly ripe female,  $28\frac{1}{2}$  inches in length. The ovaries are situated immediately above the vent, closely applied to each other by flattened inner surfaces, joined together inferiorly before the commencement of the single oviduct. Each ovary is rounded and bulging on

the outer surface, and resembles, therefore, the condition seen in many chestnuts which are on the one side convex, on the other flat. Both ovaries taken together have about the capacity of a hen's egg. The ovarian wall is thick and opaque, although near the commencement of the oviduct the pressure of the eggs from within produces a somewhat granulated appearance. The eggs are small and very numerous. After preservation in spirit they exhibit a yellowish red colour. In the fresh condition they measured about 1.25 to 4.31 mm.,\* and were therefore not quite ripe, since Collett found ova of 2 mm. in an example of this species.

Owing to the swollen condition of the ovaries, the rectum has assumed a much more horizontal inclination than is described in *M. lævis* and *M. caelorrhynchus*. The arrangement of the alimentary tract shows no peculiarity worthy of note.

The liver does not exhibit the one-sided condition seen in *M. lævis*. In the species under consideration there are two large lobes, of equal size, lying side-by-side in a similar manner to the condition already described in the case of the ovaries. The lobes extend the entire length of the upper portion of the abdominal cavity, curving over, and providing a large concavity for the superior surfaces of the ovaries. The air-bladder is again somewhat peculiar. It is almond-shaped, the narrow end being placed anteriorly. When a lateral opening is made, it is seen to be roughly divided into an anterior, middle, and posterior portions, and to be lined with a loose silvery-looking membrane which becomes convoluted and spongy in the anterior portion. An imperfect septum divides the middle from the posterior portion. The middle portion contains a complicated mass of rete mirabile; the anterior and posterior portions are simple and sac-like. There is no pneumatic duct.

The kidneys are so thin and insignificant above the bladder as almost to escape detection. In front of the bladder, however, where the solid kidney becomes divided, as in the other species of *Macruri* examined, the branches can be followed into the region of the head, where they exhibit pronounced renal or pronephric characteristics. This head-kidney has every appearance of being perfectly functional. Numerous uriniferous tubules can readily be detected in any section of it placed under the microscope, and a large ureter, which, on opening the abdominal cavity, is readily seen passing downwards posterior to the air-bladder, liver, and ovaries, can be traced forwards to this head-kidney.

The presence of a head-kidney has been noticed in all the species of *Macruridæ* which have come under our notice. The appearance of functional activity given by the presence of uriniferous tubules and a well-marked ureter is therefore of the

\*. *Vide* Holt, *supra*, vol. iv., p. 452.

more interest. *Mora mediterranea* (*loc. cit.*) is referred to as possessed of this organ also; and one or two other fishes, not obtained during the Survey Expedition, but known to inhabit considerable depths in the Mediterranean, have been described as exhibiting a persistent pronephros in the same manner—notably the various species of *Fierasfer*,\* and *Dactylopterus volitans*†. Amongst pelagic or shore fishes a head-kidney does, in some cases, exist, but, as pointed out by Balfour in 1881, it has become degenerate, and is now functionless. Balfour‡ examined the pike, eel, smelt, and angler in confirmation of his own previous statement. The angler (*Lophius piscatorius*) is generally supposed to possess only a head-kidney, and this organ is certainly functional. Parker,§ however, in supporting Balfour's conclusions, argued that this so-called head-kidney was in reality the true body-kidney shifted forward so as to occupy the position of a head-kidney.

The condition described in the case of *Dactylopterus* has been considered as pointing rather to the belief that a functional head-kidney as well as body-kidney may exist; because in the developing embryo the segmental duct and pronephros are developed at a much earlier period than the mesonephros, and must be permanently separated from all abdominal viscera before the completion of the mesonephros; and, also because from the manner in which the head kidney is incased in bone, any forward growth of a body-kidney towards this pronephric position is rendered impossible.||

The condition observed in *Macrurus rupestris* appears to us to strengthen the last argument, and at the same time to indicate that, amongst deep-sea fishes, a persistent and functional head-kidney seems to be much more common than it is amongst fishes inhabiting shallow water.

The conditions of life at great depths of the ocean is known to produce marked modifications on the fauna. In many instances this modification takes the form of degeneracy; but, in others, as in the example under consideration, an ancestral organ appears to be retained in its early condition.

#### SECTION I. (*vide*, p. 450)

(b.) Mouth inferior; infra-orbital ridge more or less distinct; dorsal spine serrated.

\* Emery, C. "Le Specie del Genere *Fierasfer* nel Golfo di Napoli." Leipzig, 1880.

† Calderwood, W. L. "Proc. Roy. Soc. Edinb.," xvii., 1890.

‡ Balfour, F. M. "Quar. Jour. Mic. Sc.," January, 1882.

§ Parker, W. N. "Brit. Assoc. Reports," 1882, p. 577.

|| Calderwood, W. L. "Journal Mar. Biol. Assoc.," vol. ii., No. 1 (N.S.), p. 43.

Sub-genus **Macrurus**.**Macrurus æqualis**, Günther. (Deep-sea.)

(Pl. XL., figs. 1, 1a.)

- Macrurus æqualis*, . . . GÜNTHER, "Ann. & Mag. Nat. Hist.," 1878, vol. ii., p. 25.  
 " " . . . GÜNTHER, "Challenger," vol. xxii., p. 134, pl. xxxii.  
 " " . . . HOLT, "Proc. Roy. Dub. Soc.," vol. vii., p. 122.  
*Macrurus smiliophorus*,\* . . . VAILLANT, "Exp. Sci. Trav. Talis. Poiss.," p. 242.

*Remarks on the Synonymy.*—Dr. Günther, in the "Challenger" Memoir, includes *Macrourus serratus*, Lowe, as a doubtful synonym of *M. æqualis*, and remarks that, the type being lost, it is doubtful whether Lowe's species is identical with *M. æqualis* or with one of the closely allied species of the sub-genus *Macrurus*. Lowe, however, distinctly described the scales in *M. serratus* as smooth, with radial striations,† a feature which should distinguish the species readily enough from any of the forms suggested by Dr. Günther. The re-discovery, in the Mediterranean, of *M. serratus* by Dr. Giglioli ‡ sets the matter at rest, as, in a courteous letter in answer to our inquiries, the Italian observer informs us that his specimens agree in all important particulars with Lowe's description. The scales are smooth, with slight radial striations, and the outer pelvic ray is produced into a long filament which reaches the twenty-third anal ray. Moreover, the mouth is sub-terminal and very wide, and Dr. Giglioli places the species in the genus (or sub-genus) *Coryphænoides*.

**DIAGNOSIS OF SPECIES.** (D. 10–13; § Pelv. 8–9.)—Snout conically projecting beyond the mouth, with rather obtuse and rough upper edge. The cleft of the mouth extends nearly to below the centre of the eye in large examples; further back, the anterior profile being also more oblique, in younger stages. Teeth of

\* In the Appendix, p. 386, the author acknowledges the identity of his species, *M. smiliophorus*, with *M. æqualis*, Günther, and refers the specimens described by himself under the latter name to a new species, *M. sublævis*.

† "Proc. Zool. Soc. Lond.," 1843, p. 91.

‡ "Nature," vol. xxv., p. 535.

§ These numbers may be reduced by one, if the very short anterior spine is omitted from the calculation.

outer series visibly stronger than the remainder. Barbel slender, not so long as the eye. The dorsal profile rises rather suddenly towards the anterior dorsal spine, especially in large specimens. The inter-orbital space is flat, or very slightly convex; its width considerably less than the diameter of the eye, which conspicuously exceeds the length of the snout, and is from two-fifths in young examples to one-third of the length of the head in large examples. In small examples the exposed surface of the scales are beset by three principal rows of rather long, slender spinelets, those of the central row the largest, subsidiary rows of smaller spinelets being also present. The number of rows increases with age, and the spinelets become relatively shorter and stouter, until in large specimens the whole of the exposed surface is closely packed by short, conical spinelets, sub-equal in length, and not arranged in definite rows. There are eight scales in a transverse series between the first dorsal and the lateral line. Second dorsal spine nearly as long as the head, armed along its anterior edge with barbs pointing upwards and rather closely set. The second dorsal fin commences at a distance from the first, which is less than the length of the head. The outer pelvic ray usually produced into a short filament reaching beyond the commencement of the anal fin.

*Colours.*—Anterior and lateral part of head and caudal region dull silvery grey. Trunk deep indigo-blue, darkening ventrally into blue-black, which extends on to the under-surface of the head. Young examples the darkest. Antero-superior part of first dorsal black. The blue colouration gradually disappears in specimens preserved in alcohol.

The above diagnosis being founded upon specimens between 13·5 and 34·5 cm. in length, the terms “large” and “small” must be interpreted accordingly.

DESCRIPTION OF SPECIMENS.—Of the seven examples taken during the Survey we select four for description, as illustrative of different stages of development. We are able to add another specimen, also from the West of Ireland, though not taken during the Survey. It is rather larger than any of our own examples, and therefore makes our series the more representative. It will be designated as *X*, the Survey specimens being termed respectively *A*, *B*, *C*, and *D*.

*Dimensions.*

	X.	A.	B.	C.	D.
	<i>cm.</i>	<i>cm.</i>	<i>cm.</i>	<i>cm.</i>	<i>cm.</i>
Total length,* . . . . .	34·5	29·10	19·00	18·00	13·50
Length of head, . . . . .	5·6	4·75	3·30	2·65	1·90
„ eye, . . . . .	1·9	1·70	1·30	1·10	·80
„ snout, . . . . .	1·5	1·05	·85	·65	·50
„ barbel, . . . . .	1·1	·70	·35	(?)	—
Width of snout, . . . . .	1·6	1·40	·75 ?	·75	·65
„ inter-orbital space, . . . . .	1·2	1·00	·70	·60	·45
„ head, . . . . .	3·3	2·50	1·70	1·30	1·00
Greatest height of body, . . . . .	5·6	4·75	2·80	1·90	1·65
„ width „ . . . . .	2·5	2·35	1·40	1·25	·85
Tip of snout to mouth, . . . . .	1·7	1·40	·80	·80	·50
„ 1st dorsal fin, . . . . .	7·2	5·65	3·90	3·25	2·40
„ 2nd „ . . . . .	10·8	9·35	6·10	4·80 ?	3·50 ?
„ pelvic fin, . . . . .	6·5	5·40	3·40	2·90	2·05
Length of outer pelvic ray, . . . . .	(?)	2·50	1·95	(?)	1·10
Greatest diameter of eye, . . . . .	1·9	1·80	1·30	1·15	·85
Least „ „ . . . . .	1·9	1·50	1·00	7·50	·60
Tip of snout to vent, . . . . .	6·5	5·80	4·10	3·10	2·45
Vent to isthmus, . . . . .	3·1	2·80	1·80	1·60	1·10
Origin of pelvic fin to vent,† . . . . .	·5	·40†	·25	·20	·15
Vent to origin of anal fin, . . . . .	1·7	1·45	1·05	·50	·65

*Proportions and Conformation.*—Owing to the defectiveness of the caudal region in most of the specimens the total length is not of much use in instituting comparisons of their relative sizes. The length of the head forms a better basis, or the distance between the tip of the snout and the commencement of the anal fin. The anus, as we shall see later, is not sufficiently constant in position to enable the pre-anal length to serve as the unit of measurement. Taking either of the dimensions suggested into consideration, it appears that the series is fairly representative of those sizes which fall within its limits.

\* In specimens *X* and *A* the caudal region is incomplete; this is also the case in *B*, which, moreover, possessed a false caudal fin. The caudal region appears to be complete in *C* and *D*.

† Measured from insertion of inner ray of pelvic fin to centre of vent.

‡ Position of vent perhaps somewhat distorted by the eversion of the ovaries.

The possession of such a series is the greatest assistance in identification, since the resemblance which each specimen bears to its immediate neighbour bridges over the discrepancy of the extremes. It is especially useful when, as in the present instance, a species has only been known previously from the description of a particular size, since the discoverer cannot be expected to anticipate the conditions in stages which he has never seen, and in attempting to do so, except in the vaguest possible manner, would only be wasting his own time and that of his readers. Hence, a small example of a species of which only the adult stage has been described might well present such differences of proportions, and other characters dependent on age or size, as to run the risk of becoming the type of a new species, ultimately destined to the fate of a synonym. We certainly know, thanks chiefly to Dr. Günther's researches, that certain proportions and characters vary with the size of the individual, as indeed is the case in all fishes, but it is impossible to compute the relations of size to degree of development of such characters with sufficient accuracy to eliminate all risk of confusing nearly allied species. Such must be our excuse for a somewhat tedious discussion of the condition of each example of the series.

In the largest example, *X*, the eye is contained about three times in the length of the head, while in the smallest it occupies only about two-fifths of that dimension. In this case the length of the eye is taken to be the distance between the most anterior and the most posterior point in its circumference. Except in the largest example it is not circular, but longer than high, its greatest actual length being in an oblique direction, parallel to the infra-orbital ridge, while its least diameter is vertical to the course of that structure. The Table of dimensions shows sufficiently that this elongation is a feature which tends to disappear with the growth of the individual, and we need only add that the flattening of the inferior margin of the eye in the specimens forming the middle of the series replaces a slight concavity in the smallest of all, which seems to indicate a very late persistence of the choroidal notch in this species.

That the alteration in the proportion borne by the antero-posterior diameter of the eye to the length of the head is gradual, and extending, *pari passu*, with the growth of the fish, is shown very clearly when the first-named dimension is converted into a decimal of the other, the result being, in *X* .33, in *A* .35, in *B* .39 in *C* .41, and in *D* .42. The growth of the snout, as compared with that of the eye, appears to be more commensurate, the former maintaining a dimension varying from three- to four-fifths of the latter throughout the series. It is certainly largest in the largest specimen, but the proportionate diminution shown by the second specimen is not regularly maintained by the remainder, the figures of the snout in terms of the eye being as follows: *X* .78, *A* .61, *B* .65, *C* .59, *D* .62. The length of the snout in *X*, therefore, is probably partly illustrative of individual variation, and not solely of developmental change.

But although the relative length of the snout does not appear to be much affected by the growth of the fish, our series shows a gradual transition in the profile of the same organ, and of other parts of the head related thereto. Before discussing this it is necessary to refer briefly to the general appearance of this region. A glance at the figure shows that the strong infra-orbital ridge is continuous with another ridge extending from the anterior extremity of the nasal bones to the apex of the snout, and thus somewhat sharply dividing the pre-orbital region into a dorsal and ventral area. It may be convenient to term this last the "rostral" ridge; and on examining the head from above it is seen that the rostral ridges meet at the apex of the snout in such a manner as to form practically a right angle, while each ridge makes a distinctly obtuse angle with the anterior part of the infra-orbital ridge of its own side. The direction of the ridges is here considered as straight, though as a matter of fact the infra-orbital ridge is somewhat convex, and the rostral ridge is, in preserved specimens at any rate, frequently concave. As such it is shown in Günther's excellent figure (*op. cit.*, pl. xxxii., fig. *c*); but it is evident from our series that the ridge may run in a straight, or even in a slightly convex, direction between the tips of the nasal and ethmoid bones; and we are strongly inclined to believe that the concavity, when it exists, is due to the collapsing of the underlying muciferous cavities by the action of the preserving fluid.

Returning to the lateral point of view, the figure (which represents the specimen here designated as *A*) shows that the obliquely upward direction of the infra-orbital ridge is continued by the dorsal ridge, and consequently the tip of the snout is above the level of the tip of the nasal bones. Such is also the case in the figure of Günther's type specimen, which is about the same size as *A*, and it is also the case, and to a rather greater extent, in *X*. However, as we turn to the smaller examples, we find that in each the level of the snout is slightly more depressed, the rostral ridge assuming a direction more nearly parallel to that of the long axis of the head and body, until, in *D*, the tip of the snout is actually rather lower than the end of the nasal bones. Very small specimens of *M. æqualis* therefore exhibit, in the profile of the snout, a closer resemblance to *M. sclerorhynchus*\* than to adults of their own species, though agreeing with the latter in the length of the organ. The mouth maintaining much the same relative distance from the tip of the snout throughout the series, and at the same time being restricted to about the same horizontal plane, it follows that the anterior profile (ventral to the snout) becomes gradually more oblique as the size diminishes and the mouth is displaced further backwards. Thus, while in *X* and *A* the angle of the jaw barely reaches the level of the centre of the eye, in *D* it extends nearly to the

\* Cf. Günther, *op. cit.*, pl. xxxii., wherein adults of both species are figured.

hind wall of the orbit. Here again we find the young exhibiting a closer resemblance to adults of another species (in this case *M. Bairdii*) than to their own, though the gradual transition of the character throughout the series leaves their specific identity in no doubt. In yet another character we find the young presenting a close resemblance to adults of other species, viz. in the direction of the posterior margin of the pre-operculum. In the larger specimens of *M. æqualis* (cf. fig. 1, or Günther, *loc. cit.*, fig. C), this scute is almost vertical in its posterior outline, whereas in *M. sclerorhynchus* and *M. Bairdii* it is decidedly oblique. It is equally oblique in our specimen *D*, but becomes more and more upright as the size increases. It is a feature which is, of course, connected with, and directly dependent on, the forward rotation of the mouth, in the greater extent of which *M. æqualis* may be said to exhibit a less degree of specialisation than the other two species.

The proportion borne by the head and trunk to the total length is rendered in this, as in many other species of *Macrurus*, of small importance, on account of the frequent mutilation of the extreme caudal region, especially in large examples. Both *X* and *A* (cf. fig. 1) seem to have lost some part of the end of the tail, as the latter terminates rather bluntly, but the proportions are much the same (head in total length, *X*  $6\frac{1}{8}$ , *A*  $6\frac{1}{10}$  ca.) in both examples, and may be representative of the condition usual in adults. Specimen *B* is obviously mutilated, and exhibits the simulation of a caudal fin so well known in this genus; but *C* and *D* appear to be perfect, the tail terminating in a long, slender filament; the length of the head, however, is contained in the total length not quite six times in *C*, and over seven times in *D*, so that either the variation in this feature is considerable, or the caudal filament in one specimen is in reality imperfect.

Dr. Günther has described in *M. rudis*, a species stated to be very closely allied to that now under consideration, a regular developmental change in the position of the vent, from a point near the origin of the pelvic fins in the young to one much nearer the commencement of the anal fin in old examples. It follows that the proportion borne by the distance between the vent and isthmus to the length of the head increases with the growth of the fish.\* No evidence of a similar developmental migration in *M. æqualis* is afforded by our series; but it does appear that the vent is subject to a rather extraordinary irregularity in position, though its relationships to the pelvic fins are practically constant. The distance between the vent and the isthmus in terms of the length of the head is for *X* .55, *A* .58, *B* .54, *C* .60, and *D* .53. The first dimension therefore seems to vary from about five- to six-tenths of the last, without regard to the size of the individual.

A character given by Dr. Günther, in his description of the "Challenger"

\* *Op. cit.*, p. 132.

specimens, is the rather sudden rise of the dorsal profile from behind the head to the anterior dorsal fin. Our figure shows that this is very well marked in specimen *A*, and it is equally conspicuous in *X*. In both these, the greatest height of the body thus attained at the level of the anterior dorsal ray is equal to the length of the head; but in our smaller examples the rise of the profile becomes less abrupt, and the greatest height of the body relatively less. In the specimen *C* the height is perhaps even less than is usual in examples of the same size, since it is relatively less than in *D*.

*Fins.*—The short stout spine, which exists at the commencement of the first dorsal in all *Macruri*, is especially well-developed in Günther's sub-genus *Macrurus*, and always projects through the skin. Hence that author speaks of the barbs as existing on the "second" ray, and apparently counts the anterior spine in enumerating the formula, though he omits it from all consideration in *Coryphænoide*s, and locates the barbs on the "first" ray in that sub-genus. The "Challenger" type specimens of *M. aequalis* are therefore credited with twelve rays in this fin. Adopting the same method of reckoning we find a variation of from 10 to 13 rays in the seven West of Ireland specimens, but 12 is the number which occurs most frequently; and the last few rays are in all cases so minute and rudimentary that a variation in their number presents no difficulty in the way of specific identity. The barbed ray is imperfect in all the specimens, but appears to have had about the same relative length throughout the series, viz. one not quite equal to that of the head. The barbs are absent from the extreme basal region of the ray, as in figure 1, in which respect our specimens appear to differ from the type, if the latter is represented\* with absolute accuracy in this rather unimportant detail. The point at which the second dorsal commences is indistinct in the smaller specimens, but appears to be much the same as in the larger, viz. at a distance from the snout somewhat less than half the length of the head. So far as the membrane of the anal fin is concerned, our figure is a restoration, as very little of it is left in the actual specimen, though the rays, about 104 in number, are in a fair state of preservation. In specimen *B*, which, as has already been stated, exhibits a simulated caudal fin, the rays of this structure are, as usual, considerably longer than those of the adjacent part of the anal fin.

It is evident that all the Irish examples originally possessed an outer pelvic ray produced into a filament, though this is now imperfect on one side or the other in most examples; and, in the rest, on both sides. When perfect it extends beyond the origin of the few anterior anal rays. In the type specimens this ray was "not, or but slightly produced,†" a description which the frequent imperfection of the slender filamentous portion renders quite compatible with the condition in the Irish examples. A more serious difficulty is the discrepancy in the number

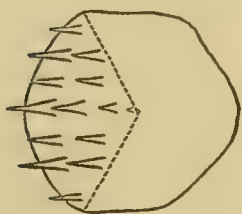
\* "Chall.," vol. xxii., pl. xxxii., fig. C.

† Günther, *op. cit.*, p. 135.

of the pelvic rays, viz. eight in the Irish examples, and nine in the type. However, the specimens which Vaillant has referred to in this species are also stated to possess eight rays, at least that is the number given in the diagnosis of his species, *M. smiliophorus*,\* acknowledged in the index to be synonymous with *M. æqualis* (Günthür); and, Dr. Günthür, who has been kind enough to examine our Survey specimens, considers our identification correct. A parallel is found in some other species of *Macrurus*, though the number of the pelvic rays is usually constant in Gadoids; and it is rather remarkable that the type specimens should exhibit that condition which appears to be the least common in the species.

*Scales*.—The type specimens, eight and nine inches long, are described as having scales “equally rough over the whole of their surface, the spinelets being subequal in size, densely packed, but arranged in from eight to twelve series, the middle series being not more prominent than the others (as in the case in *Macrurus sclerorhynchus*). The entire margin of the scale is spinous.” The figure below represents the spinelets as comparatively short and rather stout, but not entirely covering the exposed surface of the scale.

In our series we find a gradual transition in the character of the spinelets. In the smallest example, *D*, the condition differs widely from that of the types.



There are three rows of relatively very large spinelets, of which the central row is usually slightly the strongest. Two rows of much smaller spinelets occur between the larger ones, and single spinelets at the dorsal and ventral extremities of the exposed part of the margin represent the formation of the other two rows, bringing the total number up to seven. The interval between each row is

considerable, and thus a great part of the exposed surface and its margin is left destitute of spinelets, though the last of every row projects beyond the margin. In the next example, *C*, there are, unfortunately, very few scales left on the body; the usual number of rows appears to be about eight, of which only three are regular. As in *D*, the central row is the stronger; but all the spinelets of the three principal rows are relatively slightly smaller than in *D*. But, for the fact that the posterior spinelets of most of the rows project beyond the margin, the condition would be practically identical with that of *M. sclerorhynchus*† when half as large again as the example now before us; but it is reasonable to suppose that in smaller stages of that species the spinelets of the principal row are relatively larger, and the subsidiary rows fewer than in the adult, or in specimens of *M. æqualis* which agree with them in size.

Specimen *B*, allowing for the deficiency of the caudal region, is considerably larger than *C*, and we accordingly find a proportionate advance in the spinulation

\* Vaillant.

† Cf. Günther, *op. cit.*, p. 134, pl. xxxii., fig. A.

along the lines indicated by the comparison of *C* and *D*. The spinelets have increased in numbers, so that they practically cover the whole of the exposed surface; they are not very regularly arranged, but it is possible to make out about twelve rows. They have thus reached the condition in the "Challenger" type specimens (with the smaller of which *B* agrees pretty closely in size) with the exception that the median spinelets (or at any rate the posterior spinelet of the median row) are usually a little longer than the rest. The identity of the two other principal rows is practically lost; but rather large spinelets, perhaps belonging to these rows, occur dorsally and ventrally. All the spinelets are distinctly less elongated, and more conical, than in the smaller examples. A scale of specimen *a* is shown in the figure 1 *a*, Plate XL., and exhibits a further advance along the same lines. The spinelets have so increased in number that they are closely packed over the whole of the exposed surface, and it is no longer possible to arrange them in rows. About twenty to twenty-two spinelets may be counted along the anterior border of the exposed region; and although they are not all of the same size, all are short and conical, and not larger in the median row than elsewhere. Moreover, the bluntness of many spinelets seems to indicate that the limit of their growth has been reached. There is a very close approach to the condition in *M. nasutus* and *M. serrulatus*,\* especially the latter; and since the smallest known example of that species is thirteen inches long, it seems probable that it would be very hard to distinguish smaller specimens from *M. æqualis* by the scales alone. In *M. nasutus* the spinelets appear to be considerably longer. Dr. Günther mentions the close resemblance between the species before us and young examples of *M. rudis*, but since the spinelets are shown as distinctly elongated in a large example of that species, we should think that the spinulation of young stages must so far differ from that of *M. æqualis* at the same size as to furnish a distinctive character in addition to those enumerated by the author named.

*Colouration.*—Much alike in all specimens. Anterior and lateral parts of head and posterior region of trunk and tail, dull silvery grey. Anterior part of body deep indigo-blue, continued along the top of the head to the inter-orbital region, where it shades off into the grey. Posteriorly the blue shades off in specimen *a* along an oblique line running from the hinder end of the first dorsal to about the tenth ray of the anal fin. In the smaller specimens the posterior limit of the colour is further back and more vertical, the line of demarcation being at a distance from the snout about twice and a-half the length of the head. Ventrally the blue deepens into a blue-black, which is the colour of the belly, edges of the jaws and under-surface of the head, with the exception of the barbel, which is devoid of dark pigment. The pectoral fins are very dark blue; the branchiostegal membrane and pelvic fins deep black; the anterior part of the anal deep indigo-blue;

\* Cf. Günther, *op. cit.*, pp. 132, 133.

and the antero-superior part of the first dorsal black. The posterior outlines of the bones of the gill-cover, and the margin of the orbit, and of the oval groove are marked by lines of deep blue. The iris is black; the mouth closely speckled with dark pigment.

The action of alcohol tends to eliminate the blue colour; hence the specimen X, which has been longest in spirits, shows less blue than the rest. The same reason, probably, accounts for the absence of any mention of a blue colouration in the description of the type specimens, since these were only known to Dr. Günther in the preserved condition.

*Locality and Distribution.*—The Survey examples are seven in number, trawled in one haul at 500 fathoms, 54 miles off Achill Head, on the 10th July, 1890. The species was not previously known from British waters. Dr. Günther's type specimens, two in number, were taken by the "Challenger" at 600 fathoms, off the coast of Portugal. Vaillant obtained sixteen examples, from the Bay of Biscay, the coasts of Morocco and Soudan, and the Canary Islands, at depths of from 248 to 714 fathoms.

### SECTION III. (*Vide* p. 450.)

Intermaxillary teeth, uni- or bi-serial; mandibular teeth, uni-serial.

A. Dorsal spine smooth.

Sub-genus **Malacocephalus**.

**Macrurus lævis**, Lowe. (Deep-sea.)

(Pl. XL., figs. 3 and 3a.)

- |                               |           |   |
|-------------------------------|-----------|---|
| <i>Macrurus lævis</i> ,       | . . . .   | LOWE, "Proc. Zool. Soc. Lond.," 1843, p. 92.                |
| <i>Malacocephalus lævis</i> , | . . . .   | GÜNTHER, "Cat. Fish. Brit. Mus.," vol. iv., p. 397.         |
| "                             | " . . . . | LÜTKEN, "Vid. Meddel. Nat. Foren. Kjoben.," 1872, p. 1.     |
| <i>Macrurus lævis</i> ,       | . . . .   | GÜNTHER, "Chall.," vol. xxii., p. 148, pl. xxxix. B.        |
| " "                           | . . . .   | GÜNTHER, "Ann. Mag. Nat. Hist.," vol. iv., 1889, p. 418.    |
| " "                           | . . . .   | BOURNE, "Journ. M.B.A.," N.S., vol. i., No. 3, p. 311.      |
| " "                           | . . . .   | ALCOCK, "Ann. Mag. Nat. Hist.," 1889, p. 391.               |
| " "                           | . . . .   | HOLT, "Proc. Roy. Dub. Soc.," and vol. vii., pt. 3, p. 220. |

DIAGNOSIS OF SPECIES. (D. 11–13; P. 16–18; V. 8–9.)—Head compressed,

with vertical sides; snout obtusely conical, slightly projecting beyond mouth, the cleft of which is oblique, extending to the level of middle of eye. The distance from tip of snout to anterior margin of orbit equal to distance between the two anterior neres. In specimens of all sizes the greatest diameter of eye is equal to the breadth of the interorbital space. Distance from snout to base of first dorsal fin-ray equal to twice the extreme breadth of head. Teeth of upper jaw bi-serial, a toothless space occurring in the centre of the jaw; the inner series has the appearance of a villiform band. Teeth of the lower jaw uni-serial, separate. Barbel shorter than eye. Distance from tip of snout to median toothless space of upper jaw equal to distance from snout to posterior neres. From toothless space to isthmus equal to distance from isthmus to vent in specimens of thirteen or fourteen inches in length.

Scales (fig. 3a) very small, much deeper than long, covered with short, minute spinelets. In small specimens, the spinelets are few in number and large in proportion to the size of the scale.

Lower margin of preoperculum not serrated; anterior dorsal spine smooth.

A triangular, scaleless, and black-coloured depression is situated between the bases of the ventral fins. Immediately behind this, a similar depression of an oval shape occurs, and behind this oval depression lies the vent.

*Locality and Distribution.*—Twenty-five examples of this species, ranging in size from 25.5 to 54.5 cm. (10 to 21½ inches), were trawled during the Survey. One was taken in 200 fathoms, 50 miles off Bolus Head, Co. Kerry, and the remainder in water ranging from 144 to 220 fathoms, 26 to 40 miles off Achill Head, Co. Mayo.

The species appears to be more widely distributed than any of its congeners, since it occurs both in the Atlantic and Pacific Oceans.

The Atlantic specimens have been procured from the coasts of Norway (Malm)\*, Denmark (Lütken), Madeira (Lowe), Pernambuco (Günther), and the west coast of Ireland; while Pacific specimens were obtained from the Andaman Sea (Alcock).

Although the species is not mentioned amongst the results of the "Travailleur" and "Talisman" expeditions, nor from high latitudes in the records of the Norwegian North Atlantic expedition, it appears to be abundant on the slopes of the continental plateau to the west of Ireland, where, before the specimens now described were procured, it had been obtained by the "Flying Fox" (Günther) and "Research" (Bourne).

So far as the records of capture show us, the vertical range of this species is

\* "Göteb. o. Bohüsl. Faun.," p. 503. A single specimen cast up on the shore. Lütken (*op. cit.*) records that the single Danish specimen was also cast up on the Northern coast of Jutland.

only from 154 to 350 fathoms. It is probable, therefore, that it is one of the least abysmal of the *Macruri*.

*Dimensions and Variation.*—Owing to the large number of specimens procured, we are able to give two Tables, showing in the first the measurements of four carefully selected specimens of different progressive sizes, and in the second the measurements of four specimens of the same size, with a view of showing the variation which may occur. In the latter table the specimens may be roughly said to measure one foot in length, the actual variation in total length between the four specimens being half an inch.

I.—Table of measurements, given in centimetres, of four specimens of *M. lævis*, named A, B, C, and D.

	A.	B.	C.	D.
Total length, . . . . .	25·5	30·5	36·8	43·0
Length of head, . . . . .	4·0	4·8	5·7	6·7
Length of snout, . . . . .	1·1	1·3	1·7	1·9
Width of snout, . . . . .	1·5	1·5	2·0	2·3
Width of interorbital space, . . . . .	1·4	1·8	2·0	2·1
Width of head, . . . . .	2·1	2·5	3·1	4·0
Greatest height of body, . . . . .	3·3	4·0	4·9	6·0
Greatest width of body, . . . . .	1·7	1·9	2·5	3·3
Tip of snout to mouth, . . . . .	·9	1·0	1·3	1·6
„ to 1st dorsal fin-ray, . . . . .	4·4	5·4	6·4	7·6
„ to 1st fin of 2nd dorsal, . . . . .	7·4	9·0	11·2	12·9
„ to base of pelvic fin, . . . . .	4·3	4·9	6·3	7·4
Greatest diameter of eye, . . . . .	1·4	1·7	1·9	2·2
Least diameter of eye, . . . . .	1·3	1·4	1·7	1·9
Distance from vent to isthmus, . . . . .	1·9	2·4	3·2	3·7

II.—*Table of measurements, given in centimetres, showing the variation between four specimens approximately the same size, named E, E<sup>1</sup>, E<sup>2</sup>, and E<sup>3</sup>.*

	<i>E.</i>	<i>E<sup>1</sup>.</i>	<i>E<sup>2</sup>.</i>	<i>E<sup>3</sup>.</i>
Total length, . . . . .	30·4	30·0	29·0	30·0
Length of head, . . . . .	4·9	4·6	4·8	4·6
Length of snout, . . . . .	1·3	1·3	1·2	1·3
Width of interorbital space, . . . . .	1·5	1·5	1·5	1·5
Width of head, . . . . .	2·9	2·6	2·6	2·6
Greatest height of body, . . . . .	4·2	4·2	4·2	4·2
Tip of snout to mouth, . . . . .	1·1	1·1	1·1	1·1
„ to 1st dorsal fin-ray, . . . . .	5·2	5·2	5·4	5·4
„ to 1st ray of 2nd dorsal, . . . . .	8·8	8·5	8·9	8·4
„ to base of pelvic, . . . . .	5·9	4·9	4·9	4·7
Greatest diameter of eye, . . . . .	1·8	1·6	1·7	1·7
Vent to isthmus, . . . . .	2·9	2·4	2·2	2·6
Isthmus to snout, . . . . .	4·3	3·5	3·3	3·6
Vent to tip of lower jaw, . . . . .	5·8	4·7	4·7	4·8

The tail in each specimen seemed to be complete, so that we believe the measurements of total length to be accurate. It will be observed that specimen *E* is longer, by 4 mm., than *E<sup>1</sup>* and *E<sup>3</sup>*, and by 5 mm. than *E<sup>2</sup>*. This may account for a proportion of the greater measurements found in the first column, but not for the great increase which is found in the measurements of “Tip of snout to base of pelvic fin,” “Isthmus to snout,” or “Vent to tip of lower jaw.” These three measurements show that specimen *E* has a much greater distance between the various points on the ventral surface of the body; whereas the measurements on the dorsum, such, for instance, as “Tip of snout to 1st dorsal fin-ray,” show that a proportionate elongation does not take place, and that the distance may even be shorter.

The width of the interorbital space remains constant, as does the distance from tip of snout to the toothless space in the upper jaw, and the measurement of the greatest height of the body.

A variation in the general outline of the body and head exists amongst the Macruri as amongst other groups of fishes. The profile may be more boldly convex in the frontal and prefrontal regions.

The greatest actual variation in point-to-point measurement, however, is certainly found in the relative positions of the vent, isthmus, and pelvic fins; and this variation has no such developmental significance as has been demonstrated by Günther in the case of *M. serrulatus* (*op. cit.*, Pl. xxx., fig. 2*a*).

*Fins.*—An examination of a number of specimens shows a greater amount of variation in this respect than seems previously to have been recognised. The details of six specimens are here given:—

	1st Dorsal.	Pect.	Vent.
A, . . . . .	11	16	9
B, . . . . .	13	18	8
C, . . . . .	13	16	9
D, . . . . .	11	18	8
E, . . . . .	12	17	8
F, . . . . .	12	17	—

We have not found a specimen with as many as 14 rays in the first dorsal, as set down by Günther in his "Challenger" Report; and our formulæ, in introducing the numbers 12 and 16 for the dorsal and pectoral fins, respectively, seems to draw a certain additional resemblance to the formula given by Günther for *Macrurus italicus*, a form which that author shows so closely resembles *lævis* that, but for the condition of the teeth, the two would have been thrown together.

The single specimen of *M. italicus* procured by the "Challenger" was only  $5\frac{1}{2}$  inches in length. Giglioli, the founder of the species, seems also to have had only one small specimen.\* On the other hand we do not find in *lævis* more than 9 rays in the ventral fin.

*Scales.*—The scales of our smallest specimens are somewhat irregularly arranged, are very deciduous, and bear relatively long spinelets arranged in two or three very irregular rows. The condition in the adult is quite distinct (fig. 3*a*.) The scales of the young examples are apparently very similar to those described for *M. italicus*.

*Size.*—So far as we know, the largest recorded size is that of our largest specimen— $21\frac{1}{2}$  inches or 54.5 cm.

*Abdominal Viscera, &c.*—In the specimens examined the viscera seemed remarkably small, a considerable space remaining even after allowing for an unusual amount of shrinkage. The black scaleless depressions already mentioned have on their inner surfaces strong muscular attachments for the rectum and the generative ducts. The rectum comes almost directly downwards, while the generative ducts pass forwards and downwards from the posterior extremity of the abdominal cavity where the curved reproductive organs are situated. Both are borne by a

\* "Challenger Reports," vol. xxii., p. 141.

large and conspicuous mesentery. On the left side a long lobe of liver extends almost the entire length of the cavity bending into a median position for the second half of its course. On the right side the liver forms only a small leaf-like process projecting from the basal portion, but on this side of the median mesentery a fold of the intestine passes backwards. The stomach shows a well-defined fundus, the duodenum springing from the middle of the inferior surface. The pyloric coeca are very numerous; a delicate air-bladder is present. It is almond-shaped, and is covered on its under-surface by black peritoneum. On opening the bladder a circular aperture bounded by a sphincter muscle is at once visible in the centre of the median dorsal surface. This aperture has no duct in connection with it, but is merely a perforation of the upper surface. At the same time it is noticeable that the bladder is very loosely held in its position by membranes from the dorsal wall, which form a secondary cavity above and to each side of the bladder. This inclosed part of the body cavity, therefore, communicates freely with the air-bladder, and is probably utilized when the gases of the bladder increase in volume. At the anterior end, there are two rete mirabile of considerable size which may provide for such an increase; and the space found in the abdominal cavity proper, owing to the viscera not entirely filling the cavity, as already mentioned, seems also to indicate that a great increase does take place. Some such provision might be necessary if the creature has the habit of frequenting water of widely different pressures during short intervals of time, or has a much greater vertical range than the records of its capture have yet shown.

The kidneys show an arrangement not unlike that seen in *Cyclopterus*. There is a single-body kidney which divides anteriorly (at a level, in this case, of the eleventh vertebra) into two branches, which pass forwards and outwards to the region of the ex-occipitals and there forming thickened masses, may probably represent persistent head-kidneys.\* Unlike *Cyclopterus* the single-body kidney is extended backwards also. It passes down the hæmal arches of the tail to the level of the thirty-eighth vertebra. The entire organ may be said to stretch half the length of the body and tail of the fish.

In the skull, the muciferous cavities extend widely over the surface, immediately beneath the skin. Behind the eye, the opercular muscles occupy their normal position, but the skull on all other parts of its surface is soft to the touch through the presence of the cavities. The conical snout seems to form the central point from which the various channels diverge. The two cavities which occupy the interorbital space pass backwards from the region of the frontals to the level of the posterior margin of the operculum. Above the maxillæ, also, cavities extend which send slender branches upwards behind the eyes, so as almost to join the cavities of the frontal region, and thus encircle the orbits.

\* As in *Cyclopterus* and *Anguilla*, this head kidney appears to be degenerate and functionless in the adult.

## Fam.—PLEURONECTIDÆ.

Genus *Hippoglossus*, Cuvier.*Hippoglossus vulgaris*, Fleming. The Halibut. (Deep-sea.)

Only three specimens were obtained during the Survey, the depth in no case exceeding 35 fathoms. The species, however, is by no means confined to littoral waters, since it appears that, on the fishing grounds of Newfoundland, the greater number of fish are now taken at a depth of from 100 to 200 fathoms. Halibut are also regularly taken on the Faroë grounds at depths exceeding 100 fathoms.

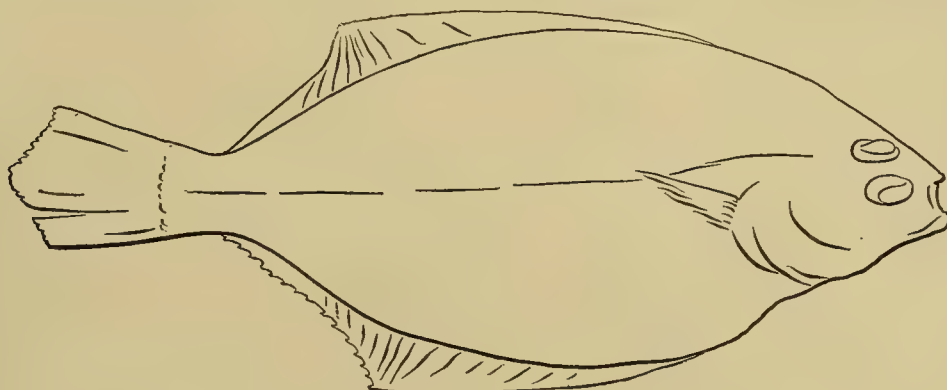
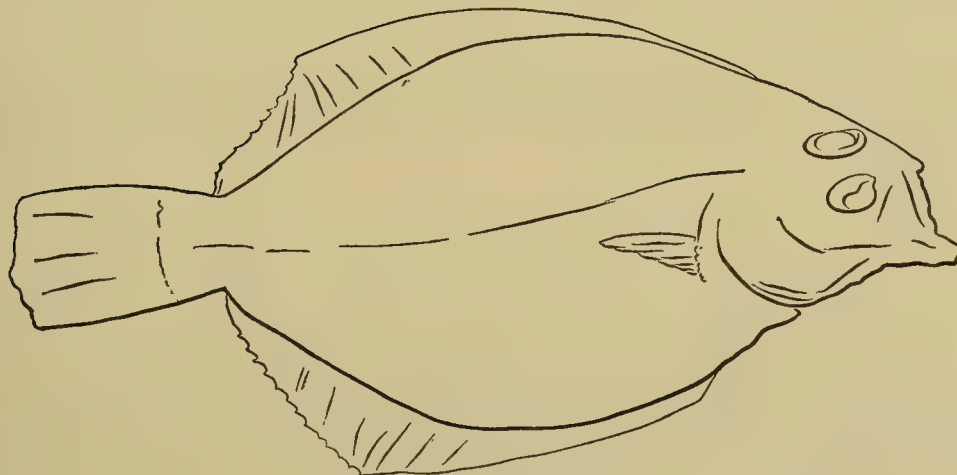
Genus *Hippoglossoides*, Gottsche.*Hippoglossoides platessoides*, Fabricius. The Long Rough Dab. (Deep-sea.)

- Hippoglossoides platessoides*, . COLLETT, "Norw. N. Atlant. Exp. Fish.," p. 144.  
 ,, ,, . GOODE, "Proc. U. S. Nat. Mus.," iii., p. 471.  
 ,, ,, . HOLT, "Trans. Roy. Dub. Soc.," N.S., v., p. 57.  
 ,, *limandoides*, . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 319,  
 403, 442.

The younger stages of this species have been dealt with by one of us at considerable length in a former number of these "Transactions," while details as to locality and depth of all specimens captured are given in the "Scientific Proceedings" (Nos. xxviii. and xxix.). The Papers last referred to having been originally prepared for the Annual Report to the Council of the Society, it was thought to be for the general convenience to make use of the nomenclature followed by Day in his "Fishes of Great Britain." Accordingly the species now under consideration appears therein under the name of *H. limandoides*, although Collett had already shown most clearly that the Palæactic and European variety (*H. limandoides*, Bloch *et auct. plur.*) is not specifically distinct from the Nearctic type bearing the older name of *H. platessoides*.

Without entering at length into the very elaborate and convincing discussion given by the Norwegian author, we may point out that two specimens in the Survey collection fully bear out his contention that the Nearctic and Palæarctic forms are not to be distinguished by their proportions. The distinction most apparent in the diagnoses of earlier writers is found in the relative height of the body, which is usually somewhat the greater in the Nearctic examples. In the same haul of the trawl, however, in Donegal Bay, we obtained two specimens of

nearly the same total length, which differed most markedly from each other in height. They are shown in the accompanying figures *E* and *F*, which are outlined from photographs. We subjoin the dimensions (after preservation in

FIG. *E*.FIG. *F*.

Two specimens of *Hippoglossoides platessoides* taken in Donegal Bay, showing difference in height of body.

alcohol), and of the others at our disposal, which most nearly approach them in size :—

—	Total Length.	Total Length without Caudal Fin.	Greatest Height of Body.	Length of Head.	Length of Eye.*
<i>E</i> , . . .	30·0 cm.	25·0 cm.	10·40 cm.	6·80 cm.	1·30 cm.
<i>F</i> , . . .	29·7	24·5	13·00	7·75	1·40
<i>X</i> , . . .	22·8	19·3	7·20	4·60	1·12
<i>Z</i> , . . .	22·6	18·6	6·65	4·56	1·15

\* It may be remarked that, in large examples, the upper eye is slightly posterior to the lower one, and not at the same level, as stated in the diagnoses of several authors.

*E*, *F*, and *Z* are from Donegal Bay, while *X* is from the east coast of Scotland, and all four examples are females. It will be seen at once that *F* is much higher than *E*, while *X* and *Z* agree well enough with *F* in this respect. *E*, *X*, and *Z* in fact represent the ordinary British type, while *F* is abnormally elevated.

To compare *E* and *F* more closely, it must be remarked that, since both specimens died with their mouths widely opened, the length of the head cannot be very exactly ascertained, though it is evident that the head is considerably the larger in *F*. The distance from the point where the lateral line reaches the operculum and the end of the caudal peduncle is in *E* 19·4, in *F* 18·1, so that the length and height of body, without head and caudal fin, stand thus—*E* 19·4 × 10·4, *F* 18·1 × 13. The greatest thickness of the body is 1·6 cm. in *E*, and 2·35 cm. in *F*. The latter is therefore, in all respects, the more massive example, as appears further from the weights—*E* 5¼ oz., *F* 8½ oz.\*

The length of the upper jaw is in *E* 2·35 cm., in *F* 2·7 cm.; that of the lower jaw, from the symphysis to the angular, in *E* 2·7, in *F* 3·1. The height of the caudal peduncle is in *E* 2·3, and *F* 2·65 cm.

In *E* 89 rows of scales cross the lateral line, in *F* 87 rows, and the fin-ray formulæ of the four examples are:—

	<i>A.</i>	<i>D.</i>
<i>E</i> , . . . .	82	61
<i>F</i> , . . . .	85	66
<i>X</i> , . . . .	87	70
<i>Z</i> , . . . .	80	61

The difference between *F* and the other specimens thus rests practically on its greater height. There is no indication of structural malformation, unless a very slight irregularity in the curve of the lateral line on the blind side can be cited as such. The dentition is the same in all the specimens, and there can be no doubt that they all belong to the same species.

Collett remarks, with justice, that the depth increases with the growth of the individual, and it may be that *F* is an old example, as the appearance of its teeth seems to indicate, which, while for some reason stunted in length of body, has continued to increase in height and other dimensions. The conclusion of that author that *H. limandoides* (Bloch) is the southern branch of *H. platessoides* (Fabr.), receives considerable support from the examination of northern and southern examples of other flat fish. Apart from the question of fin-ray formula, it is apparent, on comparing specimens of *Pl. platessa* and *Pl. limanda* from Iceland with those obtained from our own seas, that these species attain, in the northern region, a relative depth of body very much greater than their southern brethren,

\* These weights were taken after the specimens, which were preserved at the same time, had been about eighteen months in the same vessel of spirits.

though, as usual, there is great variation in this respect within the limits of either locality.

As regards its distribution, the long rough dab appears to be strictly a Northern species. In the Old Hemisphere it ranges from Spitzbergen to the English Channel, and in the New from Greenland to the New England States, while Collett suspects that it exists also throughout the Arctic Ocean. It appears to attain its largest size within the more northern parts of its range; Collett notes that one of Fabricius' types, from Greenland, measures 45.1 cm., while we have seen examples from Iceland which far exceeded in size any that are obtained in British waters. The species was taken during the Norwegian North Atlantic Expedition at a maximum depth of 223 fathoms, and it has also been found in deep water on the American coast (Goode). It was not taken during the Survey at any depth exceeding 80, or less than 25, fathoms. It is much commoner on the eastern than on the western coasts of Great Britain, and is very abundant in certain parts of the North Sea. Within the latter area it occurs, as might be supposed, in comparatively shallow water, and has been taken by one of us in the Humber, by the other in the estuary of the Forth, although it can by no means be regarded as an estuarine form.

#### Genus *Rhombus*, Cuvier.

***Rhombus megastoma*, Donovan.** The Sail Fluke or Megrim.\* (Deep-sea.)

- Arnoglossus megastoma*, . . VALLIANT, "Exp. Sci. Trav. et Talism. Poiss.,"  
p. 188.  
" " . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 122, 219,  
444.  
" " . . HOLT, "Trans. Roy. Dub. Soc.," N.S., v., p. 71.

The large size of the eyes, and, as compared with the more familiar of its congeners, the comparative slenderness of the skeletal structures, suggest a somewhat bathybial habitat for the species before us, while, on reference to known facts, it is matter of common knowledge that it is found for the most part in rather deeper water than the majority of British flat fishes. So far as the west coast is concerned, this view is fully supported by the experience of the Survey, of which details have already been given (*cf.* "Sci. Proc." p. 444). We need only recapitulate that by far the greater number of sail flukes taken came from

\* The usual name in Ireland and Scotland is "Witch," but the fish is often sold as a "White Sole," probably with a view to enhancing its value, since *Pl. cynoglossus*, the true "White Sole," is considered a better fish for the table.

more than 45 fathoms, while no less than 63 occurred below the 100 fathom line, viz. 8 at 220, 47 at 154, and 9 between 115 and 127 fathoms. We have also evidence that the parents spawn and that the young are reared at considerable depths, since ripe females were taken exclusively at 153, 154, and 220 fathoms,\* while the very young examples were most abundant between 70 and 80 fathoms—the greatest depth at which it was possible to work a fine-meshed net suitable for their capture.

The species has been described with sufficient accuracy by Day, but it may be remarked that the specimen from which he seems to have taken both his diagnosis and his drawing must have been slightly abnormal in so far as concerns the curved portion of the lateral line. This is described, and illustrated, as “almost semi-circular,” whereas an almost rectangular condition is usual. Variation in the curve, however, occurs no doubt in this, as in other species of the genus,† and we are far from impugning the accuracy of the author’s representation of the specimen in question.

The differences in colouration to which Day refers, and which are illustrated by Couch in his drawings of the “Carter” and “Sailflake,” appear to be due to the environment of the individual rather than to the existence of variety in pigmentation. Thus specimens obtained during the Survey from deep, or moderately deep, water, exhibited an uniform pale and slightly pinkish fawn-colour on the ocular side, varied, if at all, only with very faint greyish markings of indistinct outline. Such a colouration is reproduced, though somewhat unsuccessfully, in Couch’s figure of the “Sailflake.” On the other hand, the dark ring-like markings shown in the figure of the “Carter” were only noticed in specimens from shallow water—most conspicuously in one taken at 4 to 5 fathoms in Loughrosmore Bay. Though no opportunity of testing the matter occurred, it may be safely predicted that such markings might be greatly modified, if not entirely obliterated, by exposing the specimen to different conditions of light, etc., as has been already done in the case of *Solea vulgaris* by Cunningham.‡ It is less probable that markings of similar intensity could be produced on uniformly coloured examples from deep water, at all events with the same rapidity, since, in the light of the more recent experiments of the same author,§ we are tempted to infer that the absence or insufficiency of light may affect the ocular as well as the blind side of the body, and that the dark chromatophores, to the expansion of which the ring-like markings are due, may fail to develop to the same extent as in shallow-water specimens.

\* No ripe male was taken at less than 38 fathoms.

† It is frequent in *R. maximus*.

‡ “Treaties on the Common Sole,” p. 110, “Mar. Biol. Assoc.,” Plymouth, 1890.

§ “Zool. Anzeiger,” 1891; or “Journ. Mar. Biol. Assoc.,” vol. iii., No. 1, p. 111.

The sail-fluke is not included by Dr. Günther in the list of fishes collected by the "Flying Fox," but Mr. Green informs us that, during the cruise of that vessel, examples were obtained, in company with the allied *R. Boscii*, at a maximum depth of 315 fathoms. Vaillant records the capture of *Arnoglossus megastoma* at 303 fathoms off the coast of Morocco, while the same species is cited by Giglioli as having been found at considerable depths in the Mediterranean. Since, however, Day informs us that the author last quoted was the first to draw his attention to the identity of *R. Boscii* with the species now under consideration, it is uncertain to which of the two species the Mediterranean examples really belong.

On the Norwegian coast only a single example seems to have been recorded from deep water, viz. 100 to 200 fathoms off Bergen (Collett), though the species is stated to be common as far north as Trondhjem Fjord. In the North Sea the species is certainly far from common; a fact which may perhaps be cited as indicating that the physical conditions of the shallower grounds in our own seas are not so suitable as the comparatively deeper localities of the western coasts. In higher latitudes, however, it appears that the sail-fluke is frequent in very shallow water, since, as has been shown by one of us,\* trawl fishermen who work the Iceland grounds report that the majority of sail-flukes are taken close inshore, especially at the "outfalls" of rivers or streams. A few words may be devoted to the remarkable accounts placed in currency by Richardson† and Couch‡ as to the manner in which this fish finds its way to the beach, viz. by using its tail as a sail. It would be ungracious to criticise the value of the evidence of the "scientific observers" cited, since the statement in question is the only criterion by which we have any means of forming an opinion. It is, however, permissible to suggest that there are mechanical difficulties which it is necessary to explain away. The story originated in North Ronaldshay, the northernmost of the Orkney Islands, and it had long been known to one of us, on the evidence of the proprietor and his family, that sail-flukes do actually come ashore there not infrequently, but always after storms, and not "when the weather happens to be calm," as averred by Couch's informant.

A visit to the island afforded opportunity for an inquiry among the crofters, which confirmed the connection between a storm and the arrival of the fish; and though the original tale of the method by which such arrival is achieved was still current, no one could be found who had actually witnessed it. The isolated position of the place and the want of occupation of any sort in the long winter cannot be supposed to be uncongenial to the survival, possibly also the inception, of a "yarn," and we cannot but think that the sail-fluke may deservedly be relieved from this imputation of habitual self-destruction.

\* Holt, "Journ. M. B. A.," iii., 1884, p. 132.

† Yarrel, "Brit. Fish.," 2nd Sup.

‡ "Brit. Fish.," iii., p. 163.

**Rhombus norvegicus**, Günther. The Norway Topnkot. (Littoral.)

- Rhombus norvegicus*, . . . GÜNTHER, "Cat. Brit. Mus.," iv., p. 412.  
 " " . . . GÜNTHER, "Proc. Roy. Soc. Edinb.," xv., 1888,  
 p. 217, pl. iv., fig. C.  
 " " . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., 1891, pt. 3,  
 p. 218.  
 " " . . . CUNNINGHAM, "Journ. Mar. Biol. Assoc.," vol. ii.,  
 No. 4, p. 325.  
*Pleuronectes* or *Rhombus car-* CUVIER, TRIES, EKSTRÖM, KRÖYER, SUNDERALL, and  
*dina*, NILSSON.  
*Ekström's Topknot*, . . . COUCH, "Fish. Brit. Isles," p. 175.

DIAGNOSIS OF SPECIES. (D. 80-83. A. 66-67. P. 8-10. L. lat. 50 ca.)\*—  
 Exclusive of the caudal peduncle, the shape is regularly fusiform, somewhat elongate; the greatest height of the body, situate opposite the extremity of the pectoral, contained about twice and a-half to twice and two-thirds in the total length, without the caudal fin. Caudal peduncle rather conspicuously elongate, its height equal to the length of the eye. The length of the head contained about three and a-half times in the total length, without the caudal fin. The eyes from two-sevenths to one-third of the length of the head, separated from each other by a high, narrow, scale-clad, and doubly-curved ridge; the lower eye but slightly in advance of the upper, which is close to the dorsal contour; the length of the snout slightly less than that of the eye; the lower jaw somewhat prominent; the upper jaw nearly one-third the length of the head, its posterior extremity extending beyond the front margin of the eye, but short of the level of a vertical from the pupil; teeth on the head of the vomer extremely small; lateral line with a sub-semicircular curve above the pectoral fin; pectoral of ocular side much larger than that of blind side; the fourth ray the longest, extending beyond the curved part of the lateral line; equal in length to the eye and snout; pelvic fins extending beyond the origin of the anal, but not continuous therewith; dorsal and anal fins of moderate height; dorsal commences in front of the eye; its first ray may be slightly elongate, and furnished on the blind side with a tapering fold of membrane; the last few rays of both dorsal and anal rather fleshy, forming small fan-like expansion on the blind side of the caudal peduncle; caudal fin rather large, almost truncate in posterior outline.

\* These figures are based upon our own somewhat limited acquaintance with the species. Günther (Cat., *loc. cit.*) gives D. 78-80, A. 58-64.

Scales of moderate size, regularly arranged and ciliate on both sides of the body. On the ocular side they cover nearly the whole of the head, leaving only the lips, the extremity of the snout, and the eyes uncovered. Each fin-ray is accompanied by minute rough scales. On the blind side scales are absent from the jaws, the prominent parts of the pre-operculum, the outline of the gill cover, and from the fins. The greater number of the scales of the ocular side, with a somewhat angular margin, finely ciliate.

Scales may be present, however, which, when viewed microscopically, show the angle and small projections in the form of short, backwardly-directed, cone-like spines. Such scales may be most frequently found on the head, and more especially behind the eyes.

The ground-colour is a reddish chocolate, marbled with dark or black blotches. The most conspicuous blotches occur in series in the interspinous regions and along the course of the lateral line. In the latter situation there is a most conspicuous patch behind the curved part, and another a short distance in front of the caudal peduncle. Across the peduncle itself, near its origin, is a dark transverse band. The fin-rays are speckled and streaked with black. This is so more especially in the case of the dorsal and anal fins, the markings corresponding with those of the interspinous regions. Blind side unpigmented.

DESCRIPTION OF SPECIMENS.—The only example, taken during the Survey, was a male, exhibiting the following measurements:—

	CM.	INCHES.
Total length, . . . . .	7.65	3 <i>ca.</i>
Total length without caudal fin, . . . . .	6.40	2½ ,,
Length of head, . . . . .	1.90	$\frac{3}{4}$ ,,
Length of snout, . . . . .	0.50	$\frac{1}{16}$ ,,
Length of eye, . . . . .	0.60	$\frac{1}{6}\frac{5}{8}$ ,,
Length of upper jaw, . . . . .	0.70	$\frac{1}{4}$ ,,
Greatest height of body, . . . . .	2.70	1 $\frac{1}{16}$ ,,
Height of caudal peduncle, . . . . .	0.60	$\frac{1}{6}\frac{5}{8}$ ,,

In this specimen the fin-ray formula is *D* 83, *A* 67. The last three rays of dorsal and ventral form the posterior fan-like appendages on the blind side of the caudal peduncle.

The peculiar elongate scales, mentioned in the specific diagnosis, are present on the head. A few also occur on the body. These scales are shown in Van Wright's beautiful figure, in the original edition of Fries and Ekström's work. They are also visible in the inferior reproduction of the drawing in Smitt's edition. Günther's figure ("Proc. Roy. Soc., Edin.," *loc. cit.*) does not show them, nor are they mentioned in the text. This figure, however, corresponds so

closely, in all other respects, with the specimen under consideration, that we have not thought it necessary to produce another illustration.

LOCALITY AND DISTRIBUTION. — Our single example was trawled on rough ground in Donegal Bay, 25 fathoms. The species was not previously known to Irish zoology, but several specimens had been recorded by Günther from the north of the British Islands, viz. from Shetland; Lamlash Bay, off Cloch Light-house, and Kilbrennan Sound, Firth of Clyde.

Couch also recorded a specimen from the Bristol Channel, and a number of examples were subsequently taken by Mr. Cunningham at Plymouth. The species may therefore be considered as fairly distributed on the British coasts.

The species is otherwise known from the coast of Norway, while recently Petersen\* has recorded two specimens taken near Laesö, in 27 and 38 fathoms, on the Danish side of the Cattegat.

### **Rhombus Boscii, Risso. (Deep-sea.)**

*Rhombus Boscii*, . . . . GÜNTHER, "Ann. Mag. Nat. Hist.," iv., 1889,  
p. 418.

„ „ . . . . BOURNE, "Journ. M. B. Assoc.," N.S., i., 1890,  
p. 306.

In view of the close resemblance which this species has been supposed to bear to the preceding, especial care was taken during the survey that the two should not be confused. Nearly all the sail-flukes taken came under the observation of one of us during the progress of the Survey in the fresh condition, and certainly all that occurred in deep water have been examined in either the fresh or preserved condition. The results of our examination has convinced us that *Rhombus Boscii* was never taken.

This is somewhat remarkable, since several were caught by the "Flying Fox" at 150 and 315 fathoms (Günther), while many were met with by the "Research" at 200, 217, and 70 fathoms (Sts. 1, 4, and 7, Bourne).

It appears, therefore, that the species is by no means rare in deep and moderately deep water off the S.W. coast; and its entire absence from the Survey collections would seem to indicate that it does not range further to the north than the grounds worked by the "Flying Fox" and "Research." The operations of these vessels, as appears from the accounts given by Messrs. Green and Bourne, took place well to the southward of the Irish coast, whereas the most southerly

\* Petersen, "On the Biology of our Flat Fishes."—Report of the Danish Biological Station, 1894, p. 44.

haul made during the Survey occurred nearly due west of Mizen Head (see Chart, "Sci. Proc.," vii., pt. 4).

Günther (*loc. cit.*) has given a careful description of *R. Boscii*, calling attention at the same time to the work of earlier authors, of whom Vinciguerra and Kolambatovie are cited as having been the first to satisfactorily define the differences which separate it from *R. megastoma*. The author remarks that *R. Boscii* may be



Fig. G.—*Rhombus Boscii*.

recognized at a glance by its enormous eyes, and, in support of this statement, cites the dimensions of a specimen of each species.

The only specimen of *R. Boscii* at our disposal is one from the Mediterranean, in the Science and Art Museum, at Dublin, a photo-outline of which is given in the accompanying figure. It measures 26.25 cm. in total length, and, on comparison with a Survey sail-fluke of exactly the same total length from deep water, the greater size of the eyes in *R. Boscii* is not apparent. The two fish, in fact, have



Fig. H.—*Rhombus megastoma*.

eyes of the same size; though, relatively to the size of the head, the eyes are somewhat the larger in *R. Boscii*, in which species, as Günther remarks, the length of the eye is one-third of the length of the head. In the specimen of *R. megastoma* the length of the head is about  $3\frac{1}{4}$  times as great as that of the eye. In spite of this resemblance, the two fish can be recognised at a glance as distinct, without appeal to the difference in the fin-rays. The anterior profile is much more abrupt in *R. Boscii*, the upper and lower margins of the head forming a right angle at the anterior extremity. The angle so formed in *R. megastoma* is much more acute. The scales are conspicuously larger, and the bight of the lateral line

more rounded in *R. Boscii*; and, although in both specimens the greatest height of the body is about two-fifths of the total length, without the caudal, the shape is quite different. The abrupt rise of the dorsal profile in *R. Boscii* is continued backwards in a bold curve, while the ventral profile is correspondingly tumid.

The greatest height is reached at a point a little in rear of the base of the pectoral, and practically the same height is maintained as far back as a point, the distance of which from the snout is equal to the greatest height of the body. Behind this the body tapers rather rapidly towards the caudal peduncle. The sail-fluke is much more evenly fusiform in shape, the difference between the anterior and posterior tapering being less strongly marked, while the anterior profile, as already remarked, is very much more pointed. The spots on the dorsal and anal, present in *R. Boscii*, are of course wanting in the sail-fluke, though as Günther remarks that these are subject to fading, if the specimen becomes stale before being placed in spirits, it is evident that their absence cannot always be held to be of specific value.

It is quite possible that the eyes of deep-water specimens of *R. megastoma* may be larger than those of their littoral brethren, and we note that Day gives the length of the eye as one-fourth of that of the head, while in the specimen cited by Günther it measured  $\frac{1}{5}$  of the same dimensions. The specimen which we have represented for comparison with *R. Boscii* was taken from a depth exceeding 100 fathoms.

The dimensions of the Mediterranean *R. Boscii* are as follows:—

	CM.
Total length, . . . . .	26·25
Total length without caudal, . . . . .	25·55
Length of head, . . . . .	6·66
Length of lower eye, . . . . .	1·90
Length of upper jaw, . . . . .	3·20
Greatest height of body, . . . . .	9·40
Height of caudal peduncle, . . . . .	1·70

The fin-ray formula is D. 82, A. 64. The spots on the dorsal fin are between the 65th and 68th, and the 75th and 77th rays; those of the anal between the 50th and 52nd, and the 58th and 60th. The last three rays of each fin are arranged in fan-like processes on the blind side of the caudal peduncle.

#### Genus *Arnoglossus*, Bleeker.

*Arnoglossus laterna*, Walbaum. The Scaldfish. (Littoral.)

*Pleuronectes laterna*, . . . . . WALBAUM, Art. iii., p. 121.

*Arnoglossus laterna*, . . . . . GÜNTHER, "Cat. Fish. Brit. Mus.," iv., p. 417.

<i>Arnoglossus laterna</i> ,	. . .	GÜNTHER, "Proc. Zool. Soc.," 1890, p. 40.
"	"	CUNNINGHAM, "Proc. Zool. Soc.," 1890, p. 540.
<i>Platophrys laterna</i> ,	. . .	SMITT, "Hist. Skand. Fisk.," ed. ii., p. 428.
<i>Pleuronectes arnoglossus</i> ,	. .	FLEMING, "Brit. An.," p. 197.
"	"	TURTON, "Brit. Fauna," p. 97.
"	"	BONAPARTE, "Faun. Ital. Pesc."
"	"	JENYNS, "Man.," p. 465.
"	"	CANESTRINI, "Arch. Zool.," i., p. 14.
"	"	YARRELL, "Brit. Fish.," ed. iii., i., p. 644.

DIAGNOSIS OF SPECIES.—D. 84–102. A. 64–81. Vert. 39–42. Reaches a length of 20 cm.

Scales of moderate size, very thin and deciduous, their free margins ciliate on the ocular, smooth on the blind side, rather angular in large males. Lateral line with an almost rectangular curve anteriorly, its scales not pierced by sensory tubes on the blind side. Teeth of equal size.

The length of the head about  $4\frac{1}{2}$  times, and the greatest height of the body, situate about opposite the extremity of the pectoral, about  $2\frac{1}{2}$  times in the total length, exclusive of the caudal. Anterior profile rather obtuse, especially in large males; jaws subequal anteriorly, the length of the maxilla of the ocular side about 3 times in large males and young examples of either sex, about  $2\frac{1}{2}$  times in large females in the length of the head. The length of the eye about 4 times in large males, about 5 times in large females in the length of the head. Eyes separated by a very narrow, scaleless, bony ridge, the lower being in advance of the upper.

Dorsal and anal fin continued to the root of the caudal. In specimens exceeding about 13 cm. the second to the sixth dorsal rays become prolonged, the longest, in large males, being nearly equal to the length of the head. In females the longest ray does not exceed one-third of that measurement. Extremities of these rays free and filamentous.

The pelvic fin of the ocular side occupies the whole ventral edge from the isthmus to the anus. The pelvic rays become prolonged in large specimens, especially in males. Ocular side brown, with darker patches and mottlings. A black spot on the pelvic in males.

As is well known, the separation of *A. laterna* and *A. lophotes* was based, by the various authors who studied these two forms, chiefly upon certain differences in the length and character of the anterior dorsal and the pelvic rays, in the fin-ray formula, and in the proportions of the eyes and upper jaw. That most of these differences were merely sexual was first asserted by Mr. Cunningham (*loc. cit.*) in 1890, the author being led to this conclusion by the examination of a considerable number of examples of both forms taken on the S.W. coast of England.

To put the matter very briefly, he found that the elongation of the fin-rays, the large size of the eye, and the comparative shortness of the upper jaw (*i.e.* the most important characteristic of *A. lophotes*) were confined to male fish of over 13.2 cm. in total length, that in adult females the anterior rays were very slightly elongated, but that no such differences existed in examples of either sex less than 13.2 cm. long.

Taking these facts into consideration the author concluded that *A. laterna* was a sexually dimorphic form, of which examples hitherto classified as *A. lophotes* were simply full-grown males.

The greatest difficulty in the acceptance of this conclusion, and one which was present in the author's mind (*vide* p. 542), is found in the possibility of the existence of one species, in which the males and females are dimorphic, and of another smaller species which exhibits no dimorphism at all. Against this possibility the author seeks to guard by the assertion that, apart from the characters already discussed, all his specimens agreed with the descriptions given by previous writers of the species *A. laterna*, while the considerable and partial elongation of the fin-rays were confined, respectively, to males and females above a certain size. It may be permissible to suggest that the conclusion would have carried more universal conviction had it been supported by the enumeration of the proportions, &c., of a considerable series of both sexes at different sizes; this more especially since there is a discrepancy, in the fin-ray formulæ, which the author appears to have overlooked. On this account it appeared to us that any additional light, which a careful examination of the Survey scaldfish could throw on the matter, would be welcome; and, at the request of Dr. Günther, we have included in our investigation a small series of Norwegian examples.

A considerable number of scaldfish, all of the *A. laterna* type, were taken during the Survey, and about forty of these, ranging in size from 4.1 to 13 cm., were preserved. To Mr. A. R. C. Newburgh, of Bantry, we are indebted for four specimens of the *A. lophotes* type\* trawled by him on the S.W. of Ireland. The list of British examples is completed by a single *A. laterna* from the coast of Yorkshire, while the Norwegian examples, conforming to the same type, are five in number.

As is usual in the case of scaldfish, a great part of our material was considerably injured, the scales or skin being partly or wholly wanting, and the fins more or less frayed and broken, but there remain a sufficient number of specimens of which the preservation, if far from perfect, is at all events, adequate for the purpose.

We append a list of the specimens selected for examination, with a Table of those proportions which are of chief importance in the present connection.

\* *Viz.* three males with fully elongated rays, and a female with rays only slightly elongated.

*Table of Dimensions and Proportions of Irish, North Sea, and Norwegian Specimens.*

Category, . . . . .	<i>A. lophotes.</i>	<i>A. laterna.</i>	<i>A. laterna.</i>	<i>A. laterna.</i>
Locality, . . . . .	S. W. Ireland.	W. of Ireland.	Flamboro' Hd.	Norway.
Index letter, . . . . .	<i>A, B, C,† D</i>	<i>E, F, G, H, J, K, L, M,</i>	<i>N</i>	<i>O, P, Q, R, S</i>
Total length in cm., . . . .	18.5, 17.05, 16.85, 16.6	13.8, 12.0, 9.2 <i>ca</i> , 8.3, 8.1, 7.9, 8.1	12.4	12.2, 11.4, 10.2, 10.0, 10.4
Sex, . . . . .	♂ ♂ ♂ ♀ ♀ ♀	♀ ♀ ♀ ♂ ♀ ♂ ♂ ♀	♂	♂ ♀ ♀ ♀ ♀ ♂
Length of head to total length, } without caudal fin, . . . . }	.22, .22, .22, .24, .23	.21, .25, *, .23, .25, .24, .24, .25	.25	.25, .24, .24, .26, .25
Length of lower eye to length of } head, . . . . . }	.26, .26, .20, .25	.23, .23, .23, .24, .27, .23, .24, .26	.22†	.25, .23, .23, .22, .23
Length of maxilla to length of head,	.33, .31, .36, .31	.40, .39, .32, .34, .34, .33, .34, .33	.31	.31, .33, .33, .33, .32
Greatest height of body to total } length, without caudal fin, . }	.39, .40, .41, .33	.33, .38, *, .37, .38, .37, .38, .38	.43	.36, .39, .39, .37, .37

\* The specimen is so much bent that these measurements cannot be accurately ascertained.

† Eyes badly preserved.

‡ This specimen, naturally, shows only the characters of *A. lophodus*, (Günther) in a modified degree. *Vide text.*

The results which may be deduced from this Table, and from the further observations which we are about to detail, must depend, in our opinion, very much on whether the large female *C*, which we have placed amongst the specimens answering to *A. lophotes*, be accepted as specifically identical with the males, *A*, *B*, and *D*, which are typical *A. lophotes*. For ourselves we regard the female as certainly belonging to the same species as the males, in the company of two of which it was taken by Mr. Newburgh. To such minor differences as do not appear from the Table we have made reference below; and the question of the identity of females, which, so far as they are described, appear to exactly resemble our single specimen, has been discussed by Mr. Cunningham at length.

We may first state that, if there is only one species, the elongation of the fin-rays, &c., has nothing whatever to do with sexual maturity. In fact all the specimens enumerated appear to be mature, with the doubtful exception of *J*, while *L*, the smallest of the series, only measures 7.9 cm. or about  $3\frac{1}{8}$  inches in total length. Mr. Cunningham, however, claimed only a relationship between size and the assumption of the secondary sexual characters, and does not mention the maturity of the sexual organs in connection with this phenomenon.

With regard to the fin-rays, our specimens *A*, *B*, and *D*, all show the typical *Lophotes* type. The longest ray in each individual is but little shorter than the length of the head, but the order of length differs as thus:—

<i>A</i> ,	.	.	.	.	3, 4, 5, 2, 6.
<i>B</i> ,	.	.	.	.	3, 2, and 4, 5, 6.
<i>D</i> ,	.	.	.	.	5, 4, 3, 2, 6.

In the specimens cited by Mr. Cunningham the 4th ray was the longest, the order being given as 4, 3, 5, 2, 6. Hence it appears that the sixth is always the least elongated, but there is no constancy in the relative length of the rest. In all our examples there are traces of fin membrane between the basal portions of these rays, but the filamentous terminations appear to have been perfectly free. They are distinctly fleshy in appearance.

Specimen *C*, which is a female, has the longest ray a little more than a third of the length of the head, while the sixth ray is shorter than either the first or the seventh. The order of elongation of the rest is 3, 4, 2.

The pelvic rays in the three males have the elongation characteristic of *A. lophotes*, and appear to have been connected by membrane, in life, for the greater part of their length. The distal half of the membrane uniting the 4th and 5th rays of the ocular fin is black, the corresponding portion between the 5th and 6th rays being dark grey. Traces of a similar pigmentation can be detected in smaller males, but there is no evidence of its existence in any females, so that

it is probably a sexual character. The pelvic rays in the large female *C* are very slightly elongated.

Turning to those examples which are undoubtedly referable to *A. laterna*, *E*, a female of 13.8 cm., has the fourth, third, and fifth dorsal rays produced in the order named, the longest being nearly a fourth the length of the head. The smaller females of the Irish series show no traces of elongation of the rays. The largest of the males preserved is unfortunately only 9.2 cm. long. None of them have the dorsal rays perceptibly produced. The ends, however, are distinctly filamentous in specimen *J*. The smaller females, *E*, *H*, *L*, and *M* show no traces of differentiation.

The single North Sea example, *N*, a male of 12.4 cm., has the third dorsal ray slightly produced. Among the Norwegian fish, *O*, a male of 12.2 cm., has the third and second rays slightly elongated, the third ray being rather less than one-third the length of the head. None of the others have the rays at all produced.

Our series, therefore, incomplete though it is, does show such a difference in the degree of elongation of the fin-rays as might be expected if we were dealing with a single species characterized by the production of the rays in question (to an extent varying according to sex) when a certain size is obtained.

With regard to the general proportions we find nothing in the Table to indicate a distinction as between *A. lophotes* and *A. laterna*. The variation which is indicated in the proportion borne by the length of the head and the greatest height of the body, respectively, to the total length without the caudal fin seems to be chiefly individual, in so far as it is not merely developmental. The specimens agreeing with *A. laterna* have certainly a larger head, on the whole, than those possessing the characteristics of *A. lophotes*, but this is what might be expected if the former are merely younger stages of the latter. Individual variations in the height of the body is so well illustrated by comparison of *B* and *D*, both typical *A. lophotes*, that other differences in the whole series cannot be regarded as important. The single North Sea example has actually a higher body than any of the rest, but the want of other material from the same region precludes any profitable speculation as to the existence of *local* variations in this respect.

A peculiarity in shape, which does not appear from the proportions given in the Table, is the bluntness of the anterior profile in *A. lophotes*. The males, however, of this category exhibit this character more strongly than the female, *C*, while the anterior profile, though rather variable, becomes certainly more obtuse in the *A. laterna* series as the size increases.

The proportions of the eye and maxilla presented, perhaps, to some, one of the greatest difficulties in the acceptance of Mr. Cunningham's arguments as to the

identity of the two species, in the absence of an enumeration of these proportions in a series of examples extending over a considerable range of size. Our Table shows that, among specimens of the *A. laterna* type, the eye may be perceptibly larger in the male at a length of only 8.3 cm. (*cf. H* and *J*), while on the other hand no such sexual dimorphism may be apparent in specimens slightly larger (*G*), and the eye may even be largest in individual females amongst the smaller fish (*cf. M* and *R*). The proportions of the eyes in *N* are of no value, since the apparent smallness of these organs is obviously due to bad preservation. The reduction in the relative length of the maxilla in the male may evidently manifest itself in specimens of *A. laterna* of about 9 mm. (*cf. F, G, and H*), and it may (*H* and *O*) or it may not (*G*) be accompanied by a corresponding sexual dimorphism in the size of the eye. It will be noticed that, in the case of the eyes, there is a greater sexual difference in the large specimens (*A–D*), including the males conforming to *A. lophotes* than in any of the *A. laterna* type. This, as we think, tends to support rather than to refute the correctness of Mr. Cunningham's views, since a sexual dimorphism related to size would naturally become more pronounced with the growth of the individual. We also believe that the evidence which our Table affords of the occasional assumption of these features of sexual dimorphism in small examples of *A. laterna* greatly strengthens the case for the identity of the species.

Apart from the proportions of eyes and jaws, there is a discrepancy in the observed number of the dorsal and anal rays in *A. lophotes* and *A. laterna*. The value attached to even a considerable discrepancy in the case of forms in which the fin-rays are very numerous must depend largely on individual opinion, but it is certainly a matter which ought to be taken into account in an endeavour to establish the existence of a single species. Mr. Cunningham, however, only enumerates the formulæ of one male exhibiting the *A. lophotes* characters, and one large female, and of one female which, from its small size, was presumably typical of *A. laterna*. It so happens that the formula of the last-named example is considerably less than that of the other two, and is, in fact, illustrative of the discrepancy indicated by the observations of earlier writers.

In endeavouring to throw fresh light on the subject, we have counted the rays in a number of our own specimens, and have also collected the information available in existing literature.

The results are given in the following Table:—

*A. lophotes.*

	<i>D.</i>	<i>A.</i>		<i>D.</i>	<i>A.</i>
*British Museum types, . . .	95	77	†Specimen from Plymouth, ♂	101	78
* „ „ „ . . .	96	76	† „ „ „ ♀	96	75
* „ „ „ . . .	102	81	Survey Specimen, <i>A</i> . ♂	102	77
*Specimen from Lundy I., ♂	99	77	„ „ <i>B</i> . ♂	95	74
* „ „ Palermo, ♂	98	75	„ „ <i>D</i> . ♂	97	77
			„ „ <i>C</i> . ♀	93	69

*A. laterna.*

	<i>D.</i>	<i>A.</i>		<i>D.</i>	<i>A.</i>
†Specimen from Plymouth, ♀	92	69	Survey specimen, {sex not as- certained,} .	87	70
Survey Specimen, <i>E</i> . ♀	90	71	„ „ „ .	90	67
„ „ <i>F</i> . ♀	93	70	„ „ „ .	89	64
„ „ <i>G</i> . ♂	94	70	„ „ „ .	90	72
„ „ <i>H</i> . ♀	90+?	?	„ „ „ .	88	69
„ „ <i>J</i> . ♂	89+?	?	Flamoro' Hd. Specimen, <i>N</i> ♂	85	?
„ „ <i>K</i> . ♂	90	68	Norwegian Specimen, <i>O</i> ♂	84	67
„ „ <i>L</i> . ♀	89	70	„ „ <i>P</i> ♀	92	72
„ „ <i>M</i> . ♀	88	66	„ „ <i>Q</i> ♀	92	68
„ „ . . ♀	88	68	„ „ <i>R</i> ♀	90	68
			„ „ <i>S</i> ♂	87	70

It will be seen from the Table that a formula of *D.* 94, *A.* 72, is only exceeded in the case of certain of the specimens which exhibit the general characters of *A. lophotes*; therefore, if we regard the two forms as distinct species, we get the following formulæ—

$$\begin{array}{ll}
 A. lophotes, \ddagger & . . . . . D. 93-102. \quad A. 69-81. \\
 A. laterna, & . . . . . D. 84-94. \quad A. 64-72.
 \end{array}$$

\* Teste Günther. "P. Z. S.," 1890, p. 40.

† Teste Cunningham (*loc. cit.*). The sex of the Lundy Island and Palermo specimens is given on the same authority.

‡ Including the large female, *C*.

Our own observations, therefore, so far from bridging over the discrepancy, tend rather to its further illustration. So few females of *A. lophotes* are available that we cannot say whether the comparative lowness of the formula in those examined possesses any significance. It is true that among the *A. laterna* examined, the maximum of dorsal rays is exhibited by a male (Specimen *G*), but the same is also true of the minimum (Specimen *O*), and we are quite unable to state, from the material at our disposal, that there is any constant sexual difference in the number of rays in the smaller forms.

The formula, compiled after the assumption of specific identity in all the examples cited, is *D.* 84-102, *A.* 64-81. This involves a variation, perhaps, more considerable than has been demonstrated in the case of any other single species having approximately the same number of rays, but we do not think that it is by any means so excessive as to preclude the possibility of the existence of only one species. It so happens that less than 87 dorsal rays are only met with in the case of one of the Norwegian examples. Variation of the fin-ray formula, as of other characters, in relation to locality, would be in no way surprising; but Collett, who has studied the matter in the case of *Hippoglossoides platessoides*,\* found that it was the most northern examples that possessed the most numerous rays, and not the most southern, as in the present instance.

It should not be forgotten that sculdfish almost invariably arrive on deck in an extremely frayed condition. Some of our specimens are, indeed, so much injured that, as will be noticed in the Table, we have not attempted an exact definition of their formulæ; and if we admit that in the case of some other small specimens we may have failed to detect the defection of some few rays that were lost in capture, we do not believe that this will be held, by those who have had experience of the species, to be tantamount to a confession of general incompetence of observation. If such has been the case, it is quite possible that the natural condition involves no material discrepancy between the forms exhibiting, respectively, the character of *A. lophotes* and *A. laterna*; but it must be noted that Specimen *Q*, the most perfect of the whole series, has certainly a formula of only *D.* 92, *A.* 68.

The scales in the specimens forming our series are so imperfect that they can only be counted, with any approach to accuracy, in four. It is noticeable, however, that the scales of the male *A. lophotes* have the posterior margins rather more angular than in the female and in the smaller specimens (*A. laterna*). There is a difficulty in counting the number of rows which cross the lateral line in any example, as the rows crossing the anterior curved portion of this structure are so irregular that the defection of a few scales causes great confusion. It seems, therefore, preferable to enumerate the rows which cross a straight line formed by

\* "Norwegian North Atlantic Expedition," p. 144.

continuing the straight part of the lateral line forwards to the head. The result is then as follows:—

<i>A</i> ,	. . .	59 or 60, of which 47 rows cross the straight part of the lateral line.
<i>B</i> ,	. . .	57, of which 46 rows cross the straight part of the lateral line.
<i>C</i> ,	. . .	51,   ,,   40   ,,   ,,   ,,   ,,   ,,   ,,
<i>Q</i> ,	. . .	50,   ,,   39   ,,   ,,   ,,   ,,   ,,   ,,

*C* and *Q* are both females, and if the specific identity of the former with the males *A*, *B*, and *E* be allowed, there is obviously nothing in the number of the scales to separate *A. lophotes* and *A. laterna*.

As to the colours, we have already noted the existence of a black patch on the ocular pelvic, which appears, throughout the series, to be confined to males. The specimens *A* and *B* (*A. lophotes* ♂) are sufficiently perfect to show the colours of the ocular side, which, in spirit specimens, consist of a greyish brown (darkest, on account of the peritoneal pigment over the abdominal region) mottled all over with dark grey and black markings, of which the larger show a tendency to arrange themselves along the interneural regions and the lateral line. The lips and jaws are dark grey, with dark markings, and the rays of the dorsal, anal, caudal, and pelvic fins are banded with black, except on the extremities of the elongated rays. Dr. Günther ("P. Z. S.," 1890, p. 40) supposed that the markings shown in Day's figure of the Lundy Island specimen of *A. lophotes* ("P. Z. S.," 1882, pl. liii.) were reproduced from a veritable example of *A. Grohmanni*, the species with which Day identified it. Comparison with a specimen of *A. Grohmanni* in our possession shows that this might be the case without much impairing the value of the figure, as *A. Grohmanni* differs from *A. lophotes* chiefly in having a somewhat darker head. The specimen *C* has the lips and jaws a good deal lighter than in the *lophotes* males, and the fin-rays are only feebly banded with pigment.

The Norwegian female *O* has the ocular side a uniform brownish grey (darkest over the abdominal and ovarian region) very faintly marbled with a darker shade. The jaws are rather pale, and the fin-rays are only faintly pigmented. This last condition seems to hold good for all the *A. laterna* series, which are otherwise too much injured for satisfactory observation of the pigment.

After we had completed the examination of the Survey and other specimens mentioned above, Mr. Cunningham most generously placed at our disposal a large series of examples from Plymouth. These comprised 12 typical *A. lophotes* males, and six large females, showing the slight elongation of the anterior rays, similar to the female *D* of the Irish series. In addition there are seven smaller examples, five males and two females. This augmentation of our material was most valuable, since it eliminates from our work a great part of the risk which must always

accompany conclusions based on the examination of a limited number of specimens. The large females are especially valuable, since the specimen *C* was previously the solitary representative of this stage of the sex.

The Plymouth examples arrived too late to be incorporated with the rest in one series without great inconvenience, and we believe that to deal with them, as it were, in an appendix to our previous remarks will be as useful as to rewrite the whole.

The specimens agree with those described by Mr. Cunningham himself in having lost all the scales, except some of those of the lateral line, and, in most cases, a great part of the skin also, and are thus in a worse state of preservation than the few large Irish specimens. They are, however, none the less valuable for comparison.

The appended Table gives the more important particulars of the dimensions of the majority of these specimens, with their fin-ray formulæ. The individuals are denoted by Roman numbers:—

*Table of Dimensions, Proportions, and Fin-ray Formulae of Specimens communicated by MR. J. T. CUNNINGHAM.*

	LARGE MALES.				LARGE FEMALES.				SMALL MALES.		SMALL FEMALES.							
	i.	ii.	iii.	iv.	v.	vi.	vii.	viii.	ix.	x.	xi.	xii.	xiii.	xiv.	xv.	xvi.	xvii.	xviii.
Index number, . . . . .																		
Total length in cm., . . . . .	19.4	19.3	18.8	18.35	16.3	15.4	15.3	18.7	18.7	16.4	16.3	15.5	15.3	9.3	9.0	8.4	10.8	10.15
Length of head to total length, with- out caudal fin, . . . . .	.22	.22	.23	.23	.23	.24	.24	.23	.22	.22	.21	.22	.23	.24	.25	.24	.24	.24
Length of lower eye to length of head, . . . . .	.27	.27	.27	.27	.28?	.25	.29	.27	.22	.27	.26	.26	.26	.26	.23	.23	.23	.24
Length of maxilla to length of head, .	.33	.32	.30	.27	.31	.29	.29	.32	.33	.32	.33	.30	.33	.31	.31	.35	.39	.36
Greatest height of body to total length, } without caudal fin, . . . . .	.40	.39	.41	.43	.39	.39	.37	.39	.36	.40	.38	.37	.42	.39	.38	.36	.39	.38
Number of dorsal rays, . . . . .	99	102	99	97	97	99	94	98	99	96	98	97	?	92	92	89	91	91
Number of anal rays, . . . . .	75	75	78	75	79	77	76	80	78	76	78	78	76	71	70	68	68	70

A glance at the column showing the proportion borne by the length of the eye to the head shows that the sexual dimorphism in this respect is much less striking than would be inferred from the four large Irish examples, in which the female *C* has an eye conspicuously less than any of the three *A. lophotes* males. In the Plymouth series, though the average size of the eye is certainly greatest in the males, in two (viii. and x.) out of the six large females it is of the same size as in four of the males (i.-iv.), and is actually greater than in one male (vi.). It must therefore be said that sexual dimorphism of this feature is not invariably apparent even in full-grown examples. The condition of the younger examples only further illustrates the variation of the size of the eye, or of its differentiation in relation to sex, which we have already noticed in similar stages from other localities. It is not certain that any of the small Plymouth examples are sexually mature, but specimen xviii. is at least approaching that condition. With regard to the length of the maxilla the Plymouth series again greatly reduces the sexual difference apparent from the examination of the few large Irish examples, though the average larger size of this structure in the female is maintained. The condition of the younger examples so far coincides with that of the small Irish and Norwegian specimens as to indicate that the jaw is usually largest in the female at a comparatively early age.

In dealing with the larger Irish examples (*A-D*) it was noted that the profile was blunter in the males than in the female. The same conclusion is borne out by examination of the twelve males and six females from Plymouth, but in a modified degree. The profile is more abrupt and blunter in some males than in any females; but the sex of several examples cannot be distinguished by this character. The small examples, male and female, are indistinguishable from each other in shape, and are more fusiform in appearance than the largest *A. lophotes* males, and some of the largest females. They agree, however, with the smaller of the large females, and with some of the smaller *A. lophotes* males. Since the same is the case with the smaller Irish examples, it may be taken that the profile becomes blunter with age, especially in the male.

The black spot on the ocular pelvic, noted in the Irish males, is present, or at least indicated, in the Plymouth males, but cannot be detected in the females.

The variation in the elongation of the anterior dorsal rays is shown by the following figures:—

Index number.	Length of head.	Length of longest ray.	Order of elongation.
♂ i.	3.60 cm.	3.30 cm.	3. 4. 2. 5. 6.
„ ii.	3.70 „	3.75 „	3. 4. 5. { <sup>6</sup> <sub>2</sub> . 7.
„ iii.	3.60 „	2.90 „	4. 3. 5. 2. 6. 7.
„ iv.	3.60 „	3.00 „	3. 4. 5. 2. 6.
„ vi.	3.10 „	2.70 „	3. 4. 5. 2. 6.
„ vii.	3.08 „	2.40 „	4. 5. 2. 3. 6.
♀ viii.	3.70 „	1.40 „	4. 3. 2.
„ ix.	3.60 „	1.70 „	3. 2. 4.
„ x.	3.10 „	1.15 „	3. 2. 4.
„ xi.	3.00 „	1.20 „	{ <sup>2</sup> <sub>3</sub> 4.
„ xii.	3.00 „	1.30 „	3. 2. 4.
„ xiii.	3.00 „	1.30 „	3. 2. 4.

In the smaller examples of either sex the anterior rays are not elongated. It will be noted from the above enumeration that there is no constancy in the order of elongation in the males ; also, that the longest ray may be actually longer than the head (specimen ii.), and that the seventh ray may be elongated (specimens ii. and iii.), conditions which appear to have escaped the attention of other observers. The elongation of the anterior rays in the large females seems to be confined to the 2nd, 3rd, and 4th rays, and, in the small series before us, shows a certain regularity in order. Taking all our material into consideration it appears that, in either sex, the 3rd ray is usually the most elongated, and the 6th (or 7th) the least.

The fin-ray formulæ of the large Plymouth females serve to show that the sexual discrepancy in the large Irish examples is, so to speak, a matter of chance, and not due to sexual dimorphism ; but, as in the case of the Irish series, we again find that the formulæ of the small specimens is lower than that of the large ones. The enumeration of the rays of the large males and females certainly tends to associate them as one species ; but the difficulty presented by the discrepancy between these (which we may term *A. lophotes*, ♂ and ♀) and the smaller undifferentiated examples of either sex is by no means lessened by the Plymouth material.

The state of the specimens was such that we were only able to count the scales of the straight part of the lateral line in five examples, all small. The number varied from 38 to 40, being 38 in two, 39 in one, 39 or 40 in one, and 40 in one. In two specimens the total number of rows of scales between the head and the caudal fin could be ascertained. In one it is 48, in the other 50. Thus the small Plymouth examples agree with the Norwegian specimen *Q*, and with the large Irish female *C*, but have a considerably less number of rows than the Irish *A. lophotes* males *A* and *B*.

It appeared probable that information of value might be gained by counting the vertebræ, which we accordingly exposed in several specimens, with the following results:—

<i>A. lophotes</i> , male, . . . Plymouth, .	D. 99	A. 77	Vert. 41.
" " " " " "	" 94	" 76	" 42.
" " " " " "	?	?	" 41.
" " large female, " " "	" 97	" 78	" 42.
" " " " " "	" 98	" 78	" 41.
" " small male, " " "	" 89	" 68	" 39.
" " " " " "	?	?	" 39.
" " small female, " " "	" 91	" 68	" 39.
" " small male, Ireland, .	" 94	" 70	" 39.
" " small female, " " "	" 88	" 66	" 39.
" " " " " "	" 90	" 71	" 39.
" " " " " "	" 93	" 70	" 39.

It is apparent that, if we have counted correctly, all the small examples have 39 vertebræ, and all the larger ones, whether male or female, either 41 or 42 vertebræ. Since the number of vertebræ is known to roughly correspond in Pleuronectids to the number of the fin-rays, it seems probable that the small examples have actually a less number of fin-rays than the large ones, so that the difficulty is not to be explained away as due to an error in counting the rays. We are not aware of any observations showing that the number of either rays or vertebræ increase with age, and do not regard this as probable. A variation of two or three in the number of the vertebræ in a species is by no means remarkable, but it is remarkable that we should have found such a constant variation in relation to the size of the individual. The variation is confined to the caudal region, the number of abdominal vertebræ being nine in both large and small examples.

Taking all our information into consideration it appears to us that the evidence of the identity of *A. laterna* and *A. lophotes* is sufficient to outweigh the difficulty

presented by the fin-rays and vertebræ, the more especially since the large Irish female *C* is a connecting link between the fin-ray formulæ of the larger and smaller forms, and probably also in regard to their vertebral formulæ.

We have accordingly included *A. lophotes* in our list of synonyms. A further argument to the same effect is perhaps furnished by the absence of any small examples that can be said to belong to *A. lophotes* rather than to *A. laterna*.

Although in this Paper we have given details of no specimens of a less total length than 7·9 cm., we have examined practically all lesser sizes of adult form, and can detect no difference to which specific value could possibly be assigned. The smallest specimens have been described and figured by one of us in a previous number of these "Transactions."\* On the other hand it will be argued that no fish exhibiting the characters of *A. lophotes* have been recognised from Scandinavian waters, where *A. laterna* appears to be fairly plentiful. It must be remembered, however, that, previous to 1822, *A. lophotes* was only known to science from three dried skins of unknown locality; the number was then increased by the capture of the Lundy Island specimen, and when, in 1890, Cunningham first recorded the abundance of this form on the S.W. coast of England, only one other specimen (from Palermo) had been added, while this Paper furnishes the first record of the existence of the form in Irish waters. Hence it is no slur on Scandinavian naturalists to suggest that *A. lophotes* may yet be discovered within the Scandinavian area.

But there is another consideration which may not be without weight. It is matter of common knowledge that the growth of fishes is greatly affected by conditions of food and environment. This being so, may it not be that a species, which, in certain localities, attains a large size, accompanied by developmental and sexual metamorphosis of several structural characters may, in a district less favourable, remain permanently stunted, and fail to exhibit the final metamorphosis?

In the case of the Salmonidæ we know that this may happen; and the analogy of this family leads us to a speculation as to the probable factor of the evolution of the secondary sexual and late developmental characters of the scald-fish. We have seen that they are in no way related to sexual maturity, but simply to size.

The experiments of Sir J. Gibson Maitland (to whom we are indebted for much courteous information in answer to our inquiries), in the breeding of Lochleven trout, have established the fact that the offspring of young parents retain, throughout life, a great similarity to the common brown trout (*S. fario*), whereas the offspring

\* "Trans. Roy. Dub. Soc.," vol. v. (series II.), p. 75.

of old parents pass through the various "smolt" and "grilse" stages, and finally resemble their parents in every respect.

If, as we are entitled to assume, the attainment of a large size is for the advantage of the species, it is obvious that that advantage would accrue from the development of any character which would induce the largest fish to mate with each other; such a character is presumably furnished in the case of large *S. levenensis* by the peculiar pigmentation of the adult, and it is possible that the more pronounced characters (in this case sexually dimorphic) of the scaldfish may be interpreted in the same way. It so happens, however, that Sir J. Maitland finds that the size of the male parent is of no apparent importance in trout, and that the size of the offspring depends on the size of the egg, which, in turn, is in proportion to the size of the parent female.\* Such being the case, the object of the accessory sexual characters of the male scaldfish is not apparent, if we were not aware that there is a mechanical difficulty in the fertilization of the ova of young females by the spermatozoa of old males, which Sir J. Maitland informs us is the case. From this it is evident that an old male can only reproduce its species by union with a mate of corresponding size, and possibly the elongated rays of the old male scaldfish may assist in securing this object. In any case it seems quite reasonable to suppose that, as in the case of the Lochleven trout, the offspring of young or small scaldfish may never attain the characters of the full-grown fish, so that within the limits of one species there may be two well-marked forms—one attaining a large size, and becoming sexually dimorphic, while the other remains permanently stunted and practically indistinguishable as to sex by external characters.

It may be further conjectured that the elongation of the rays in old males is not merely, as it were, ornamental, but of actual service in the discharge of the sexual function. Little is, or is likely to be, known of the breeding habits of sea fish, but it is quite possible that there may be some sort of conjugation in which the elongated rays may play an important part as organs of prehension.

A Mediterranean scaldfish, *A. conspersus*, Canestr., is considered by Professor Smitt to be identical with *A. laterna*. On this matter we have no opportunity of offering an independent opinion. In discussing the species, Smitt makes no mention of Mr. Cunningham's Paper, either in the list of references or in the text. This might be taken as a rather forcible method of indicating dissent from the views therein expressed, were it not that the author, though he has chosen to publish in English, shows no signs of having attempted to make himself acquainted with the observations of recent British writers.

\* A fact which probably holds good for sea-fishes, and accounts for the discrepancies in statements by different writers as to the dimensions of the ovum of a species.

**Arnoglossus Grohmanni, Günther. (Littoral.)**

- Pleuronectes Grohmanni*, . . . BONAPARTE, "Fauna Ital. Pesc."  
 " " . . . CANESTRINI, "Arch. Zool.," i., p. 12.  
*Arnoglossus* " . . . GÜNTHER, "Cat. Brit. Mus.," iv., p. 417.  
 " " . . . CUNNINGHAM, "Proc. Zool. Soc., London," June, 1890.  
 " " . . . HOLT, "Proc. Roy. Dub. Soc.," vii., p. 228.

DIAGNOSIS OF SPECIES (D. 86–90; A. 60–67; P. 9–10; V. 6; C. 17; Lat. L. 56).—The height of the body two-fifths of total length (without caudal). Scales deciduous. Lower jaw slightly prominent; the length of the maxillary is rather less than one-third of that of the head. Eyes very close together, the lower in advance of the upper. The second dorsal ray separate, elongate. A dingy brown, clouded with darker patches, arranged in three irregular rows.

Previous to the Survey only two specimens of this fish had been taken in British waters: one obtained by Mr. Spottswood Green from the Kenmare river, in 10 fathoms; the other by Mr. Garstang, described by Mr. Cunningham (*loc. cit.*), in Cawsand Bay, Plymouth Sound, in 4 or 5 fathoms. Four examples are now added as a result of the Survey, one an adult male, and three young specimens, taken at Killybegs. It therefore seems probable that this Mediterranean fish is more common on our coast than had been supposed. In the above diagnosis we have followed Günther as to the relative height and length of the species, because our adult example exactly corresponds with this statement. In the specimen described by Cunningham, the greatest height is stated as "being contained  $2\frac{1}{2}$  times in the total length, including the caudal fin." Unfortunately the length of the caudal fin is not stated. Since, however, the length of our adult specimen with the caudal fin added, is, as nearly as possible, twice the extreme height (including dorsal and anal fins), the Plymouth specimen may be of less height. This appears the more likely, since, in another part of Mr. Cunningham's Paper, the extreme length is given as 15·3 cm., the extreme breadth as 5·7 cm.

The fin-ray formula has been constructed from the observations of Canestrini, Cunningham, and from our own specimen.

Canestrini D. 90; A. 60–67.

Cunningham D. 87; A. 66; P. 10; V. 6; C. 17.

Survey specimen D. 87; A. 63; P. 9; V. 6; C. 17.

The great variation in the dorsal and anal fins stated in our diagnosis springs, therefore, from Canestrini's data. We have disregarded the formula of Bonaparte, as showing an excess of variation, or, at all events, a variation which appears to be improbable from the study of British specimens. His formula is D. 80; A. 52; Lat. line, *ca.* 45.

In view of the deciduous character of the scales, we are fortunate in having an almost complete specimen. We have, therefore, no hesitation in giving the number of scales on the lateral line as 56. The scales of the upper side have setose margins, those of the under side are smooth. In our specimen the second and third dorsal fin-rays are elongate, the second being pronounced in this respect (1.5 cm.) in conformity with the character of the species. The first and second are alone free. In the Plymouth specimen the second, third, and fourth rays are elongate, the second having a broad plicated membrane stretching to an equal extent on both anterior and posterior sides of the ray, the whole tapering and curving towards the tip. In our specimen the membrane is not conspicuous on the anterior side, nor can it be described as at all plicated. It gives the appearance rather of a primary feather from a bird's wing. The conditions exhibited by the two specimens show that either this secondary sexual character is capable of considerable variation, or, as is more likely, our adult example (which is smaller than Cunningham's) is in a stage intermediate between that of the young examples, in which the rays, though separate, show no membranous margins, and that shown in Cunningham's specimen, which is figured.

The proportions of our adult specimen may be more clearly understood from the following measurements:—

Length, including caudal fin, . . . . .	12.1 cm., or $4\frac{3}{4}$ inches.
Length without caudal fin, . . . . .	10.0 „ or $3\frac{1}{8}$ „
Extreme height, . . . . .	6.3 „ or $2\frac{1}{2}$ „
Height without fins, . . . . .	4.5 „ or $1\frac{3}{4}$ „
Length of head, . . . . .	2.7 „
Length of eye, . . . . .	0.7 „
Length of second dorsal fin-ray, . . . . .	1.5 „

### Genus *Pleuronectes*, Günther.

*Pleuronectes cynoglossus*. The Craig-fluke or Pole-dab.\* (Deep-sea.)

<i>Glyptocephalus cynoglossus</i> , .	GOODE, "Proc. U. S. Nat. Mus.," iii., 1880, p. 475.
„ „ .	GOODE, "Bull. Mus. Comp. Zool.," x., 1883, p. 195.
„ „ .	COLLETT, "Norw. N. Atlant. Exp. Fish.," p. 150.
„ „ .	COLLETT, "Forh. Vid. Selsk. Christ.," 1880, p. 82.
„ „ .	STROM, "Norsk. Vid. Selsk., Skrw.," 1884, p. 39.
<i>Pleuronectes</i> „ .	HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., p. 121.
„ „ .	HOLT, "Trans. Roy. Dub. Soc.," N.S., v., p. 84.

\* This fish is called "Witch," or "Witch Sole," on the East coast of Great Britain. It is the "White Sole" of the Dublin market, though *R. megastoma* is also frequently dignified with that title for commercial purposes.

This is the only flatfish known to descend beyond a depth of 500 fathoms. It has been recorded by Goode, from off the Atlantic coast of the United States, at depths of 120, 263, 395, 603, and 732 fathoms; by Collett, off Lofoten and Finmark, at 125 to 150 fathoms; by Strom, in Trondhjem Fjord, at 200 fathoms; and by Bourne, off the S.W. of Ireland, at 200 fathoms. During the Survey three specimens, from 5 to 6 inches in length, were trawled at 144 fathoms, and four others, larger, but of no great dimensions, were taken at 220 fathoms. The species was also met with in littoral waters (*vide* "Sci. Proc.," vii., pp. 343, 409, 447).

In the large size of the eyes, and comparative slenderness of the structural parts, *P. cynoglossus* bears a certain resemblance to *R. megastoma*, and it may be said that the two species have very much the same vertical distribution on our own coasts, the former occurring most abundantly on the east, and the latter on the west coast. In northern latitudes craig-flukes are found in quite shallow water, as at Iceland,\* as well as at the considerable depths noted above; but the species does not appear to have been met with by the French "Travailleur" and "Talisman" expeditions at any depth in the South Atlantic; and the Bay of Biscay, where it is known to occur, at moderate depths, in some numbers, is perhaps the southern limit of its range.

Collett (*op. cit.* p. 151) was the first to demonstrate that *P. elongatus*, Yarrell, is merely a young stage of *P. cynoglossus*. In dealing with the development of the species in a former number of these "Transactions" (*t. c.* p. 88, pl. xv., fig. 124) an example, illustrative of the *P. elongatus* stage, has been given by one of us.

### Genus *Solea*, Klein.

#### *Solea vulgaris*, Quensel. The Common Sole. (Deep-sea.)

*Solea vulgaris*, . . . . VAILLANT, "Exp. Sci. Trav. Talism., Poiss.," p. 189.

The sole must be admitted into the category of deep-sea forms on the strength of the capture of a specimen by the French scientific expedition, at 127 fathoms, on the Banc d'Arguin. The species is well known to congregate in certain of the deeper parts of the North Sea in hard winters. The Great Silver Pit, the most noted of these grounds, has a maximum depth of about 60 fathoms, which is, we believe, with the exception referred to above, the greatest depth at which soles are known to have been taken.

\* *Vide* "Journ. M. B. Assoc.," iii. 1894, pp. 130, 132.

**Solea lascaris**, Risso. The Lemon-sole or Sand-sole. (Littoral.)

Three examples were taken in Blacksod Bay, viz. two on the trawling-ground, at  $5\frac{1}{2}$  to 9 fathoms, and one at the margin in the small inlet known as Dugort Bay.

**Solea Greenii**, Günther. (Deep-sea.)

- S. Greenii*, . . . . . GÜNTHER, "Ann. Mag. Nat. Hist.," iv., 1889, p. 419.  
 ,, . . . . . BOURNE, "Journ. M. B. Assoc.," N.S., i., 1890,  
 p. 312.  
 ,, . . . . . CUNNINGHAM, "The Common Sole, Plymouth,"  
 Mar. Biol. Assoc., 1890.

The species is known from only two examples. Of these, the first was taken by Mr. Green, in the "Flying Fox," at 150 fathoms, and the second by Mr. Bourne, at 217 fathoms, in both cases off the S.W. coast of Ireland. The species has been described by Dr. Günther and by Mr. J. T. Cunningham. It appears to be of no great size, since a specimen of 18·8 cm. was found to be a sexually mature female. It is regarded by Günther as allied to *S. vulgaris* and *S. variegata*, between which two forms it is in some particulars intermediate. By comparison of descriptions it appears to us to closely resemble *S. profundicola* (Vaillant), a deep-water sole from the South Atlantic.\*

**Solea variegata**, Fleming. The Thickback. (Deep-sea.)

- S. variegata*, . . . . . VAILLANT, "Exp. Sci. Trav. Talism. Poiss.," p. 190.  
 ,, . . . . . GÜNTHER, "Ann. Mag. Nat. Hist.," iv., 1889, p. 419.

An example, 4 inches long, was trawled at 40 fathoms in Dingle Bay, and another, about one inch long, was found in the stomach of a piper gurnard taken at 62 to 52 fathoms off the Skelligs. The thickback is known to habitually frequent rather deep water. There are two records of its occurrence beyond the 100 fathom-line, viz. at 162 fathoms in the Bay of Biscay, (Vaillant) and at 150 fathoms off the S.W. of Ireland (Günther).

\* Vaillant, "Exp. Sci. Trav. Talism., Poiss.," p. 190.

## Fam.—SALMONIDÆ.

Genus *Argentina*, Artedi.*Argentina sphyræna*, Linnæus. (Deep-sea.)

- A. sphyræna*, . . . . . COLLETT, "Norg. Fisk.," p. 171.  
 ,, ,, . . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., pp. 122,  
 220.

When dealing with the genus in his "Challenger" Memoir,\* Dr. Günther considered that the European species of *Argentina* lived at a considerable depth, but probably not at the bottom, since, at the time of writing, they had not been captured by the dredge, or trawl, during any of the deep-sea expeditions. During the Survey, however, a considerable number of *A. sphyræna* were taken in the trawl. This is not necessarily a proof that the specimens were caught at the bottom, since they may have entered the net during either its ascent or descent, but it is significant that the greatest number were taken in company with essentially bottom forms, such as flatfish and gobies, and with *Gadus argenteus*, a species probably referable to the same category.†

Several specimens were also found in the stomach of a skate (*R. oxyrhynchus*), a fish which presumably does not range very far from the bottom in pursuit of food. The specimens captured were distributed as follows:—A considerable number, about  $1\frac{1}{2}$  inches long, at 62 to 52 and 80 fathoms, off the Skelligs; several, a little larger, in the stomach of the skate, trawled at 500 to 375 fathoms, off Achill Head; three,  $3\frac{1}{4}$  inches long, at 40 fathoms, and one,  $5\frac{1}{2}$  inches long, at 53 fathoms, in Dingle Bay.

The species thus appears to be not uncommon on the west coast, as seems also to be the case on the west of Scotland, whence Günther has recorded a considerable number from 32 to 27 fathoms. Collett found specimens in the stomach of a ling caught at 200 fathoms, on the coast of Norway, apparently the only exact record, previous to the present, of its occurrence below the 100 fathom line.

The appearance of the smaller specimens is shown in fig. *J*, which represents a spirit specimen, 37 mm. in total length, magnified three diameters. The head and eyes are, of course, much larger, relatively, than in the adult. There are no scales, but the skin is silvery, especially on the sides and gill-cover: the eye is

\* "Chall. Rep. Zool.," xxii., p. 217.

† For full list of other species see results of Sts. 114 and 115 ("Sci. Proc.," vii., pp. 258, 259). *A. sphyræna* has been accidentally omitted.

silvery, with black markings. Black pigment is present, chiefly in the form of isolated chromatophores, or small groups of chromatophores, but there is a dark patch on the top of the head, as in the adult, and another at the base of the pelvic fins. Eight small groups of chromatophores occur along the course of the lateral line, and the base of each ray of the first dorsal and anal fin is decorated with a black spot. The dorsum is finely powdered with small dark dots, while larger ones occur on the gill-cover and at the caudal extremity. There is a groove along the dorsum, from which arise the basal ridges of the nine rays of the first dorsal fin. The sides are slightly flattened, and the ventral abdominal region is somewhat biconcave. Beyond this there is no trace of the polygonal shape (in section) of the adult (*cf.* Day, "Fish. Gt. Brit.," ii., pl. cxxv., fig. 2).

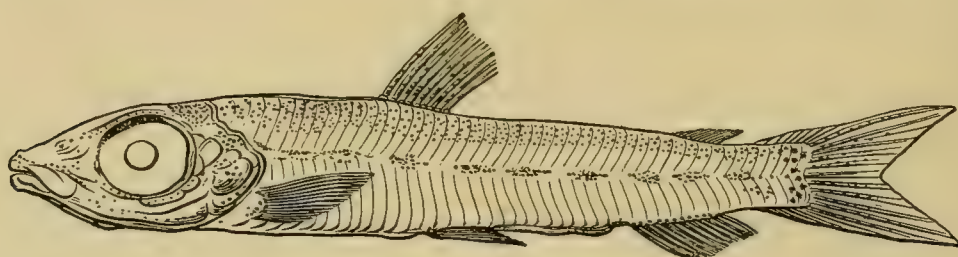


FIG. J.—*A. sphyraena*, Juv. Reduced  $\times \frac{1}{4}$ .

Fam.—**MURÆNIDÆ.**

Group **Anguillina**, Günther.

Genus **Conger**.

**Conger vulgaris**, Cuvier. The Conger. (Deep-sea.)

*C. vulgaris*, . . . . . HOLT, "Sci. Proc. Roy. Dub. Soc.," vii., p. 220.

A large specimen was trawled at 154 fathoms, 28 miles off Achill Head, on 20th April, 1891.

Off the Inner Hebrides, Scotland, a few boats from the east coast carry on a conger fishery in deep depressions of 70 to fully 100 fathoms.

Group **Murænesocina**, Günther.

A small eel, trawled at 144 fathoms, off Achill Head, forms the type of a new genus and species, of which one of us has already given a description, now reprinted with a few verbal alterations.

Genus *Nettophichthys*, . . . HOLT, "Sci. Proc. Roy. Dub. Soc." vii., p. 122.

Scaleless. Snout much produced; depressed. Jaws and vomer with rows of teeth, recurved in anterior region, largest in central region of vomer. Gill openings fairly wide, open. Vertical fins confluent, rather feebly developed. Pectoral fins absent. Anterior nostril on upper surface of head near end of snout. Posterior nostril on side of head in front of eye. Air-bladder present. Pyloric appendages absent.

As will be seen from the above description, this genus is intermediate between *Nettastoma*, Raf., and *Saurenchelys*, Peters, agreeing with the latter in the condition of the nostrils, and with the former in the possession of an air-bladder. In the comparatively feeble character of the vertical fins it recedes equally from both.

#### TYPE SPECIES.

*Nettophichthys retropinnatus*, Holt, *loc. cit.* (Deep-sea.)

(Pl. xli., fig. 2.)

Length of head contained six times in total length (without caudal) and equal to distance between gill opening and anus. Eye large, diameter contained twice in snout, and five times in length of head. Angle of gape behind hinder margin of eye. Upper jaw slightly overhanging lower; snout broad, swollen, except where produced anteriorly into a short knob-like deflected process, at base of which is situated anterior nostril. Lower jaw slightly curved. Teeth in two rows, outer most closely set, along margin of upper jaw, small and conical posteriorly, becoming larger and recurved in anterior region. Large abruptly reflected teeth, with swollen bases, in several rows on vomer, those of central region largest. A single row of small recurved teeth on mandibles, becoming larger towards symphysis.

Body laterally compressed: greatest height, *i.e.* behind anus, nearly half length of head. Abdominal cavity extending beyond anus; peritoneum black; air-bladder long. Tail tapering, but terminating obliquely. Extremity of vertebral column not upturned, overlying triangular hypural mass. Vertical fins rather feeble, especially dorsal, which commences at a point somewhat posterior to median. Vertical fins edged with black, especially caudal and anal.

Coloration, uniform sepia brown, darkest ventrally, and on snout and jaws.

A single specimen, 5 inches, much injured, from 144 fathoms. It appears to be sexually immature.

## ALPHABETIC LIST OF SPECIES.

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PLATE XXXIX.

SURVEY OF FISHING GROUNDS, WEST COAST OF IRELAND, 1890-1891.

EXPLANATION OF PLATE XXXIX.

Figure

1. *Haloporphyrus eques*, Günther (p. 446).  
Small specimen, first dorsal fin-ray moderately extended, but complete. Barbel not visible.
2. *Haloporphyrus eques*, Günther (p. 446).  
Large specimen, first dorsal fin-ray incomplete. Skin of head somewhat shrunken where muciferous cavities occur.
3. *Mora mediterranea*, Risso (p. 436).

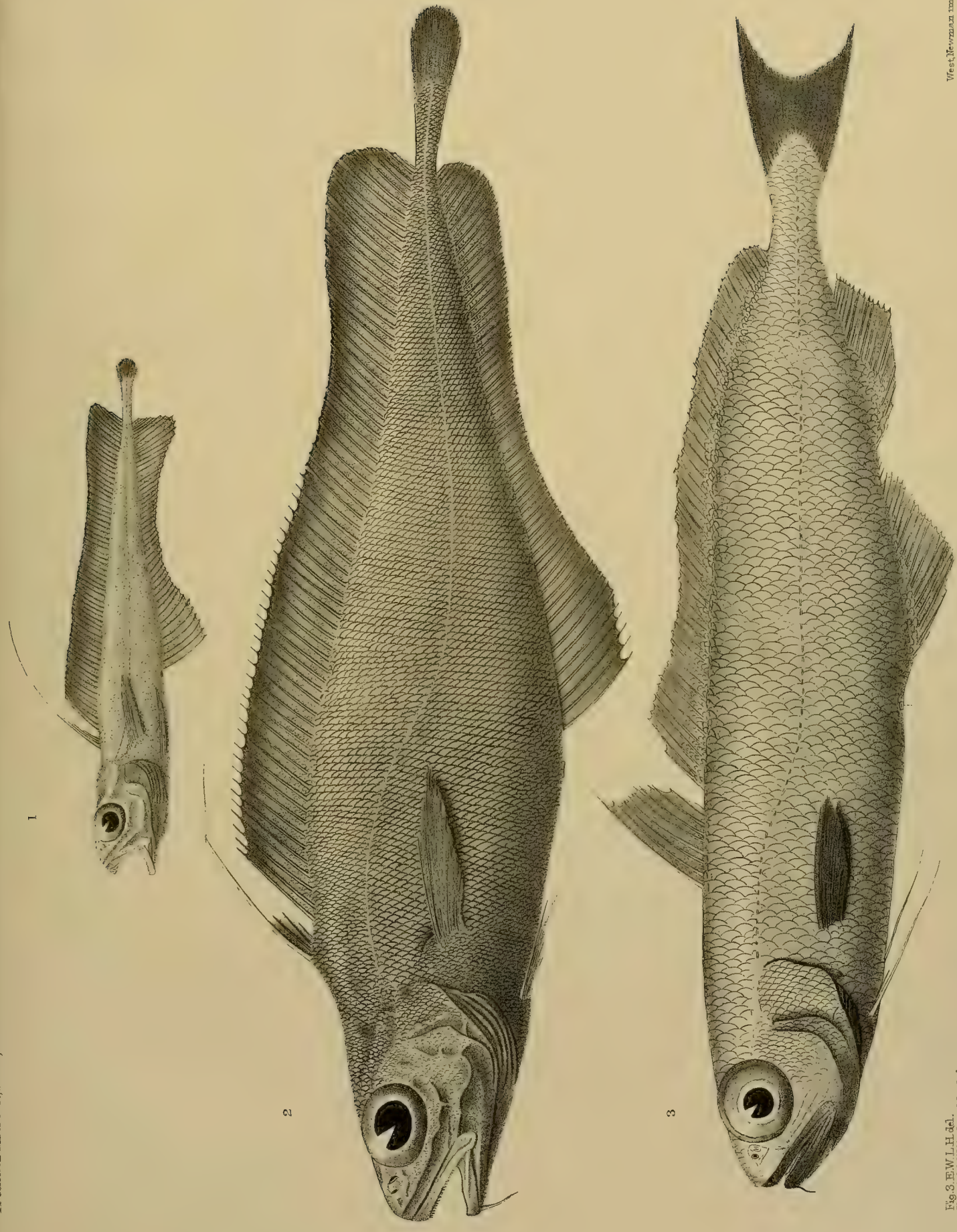


Fig. 3. E.W.L.H. del.  
Figs. 1, 2. M.P. Parker del. et lith.



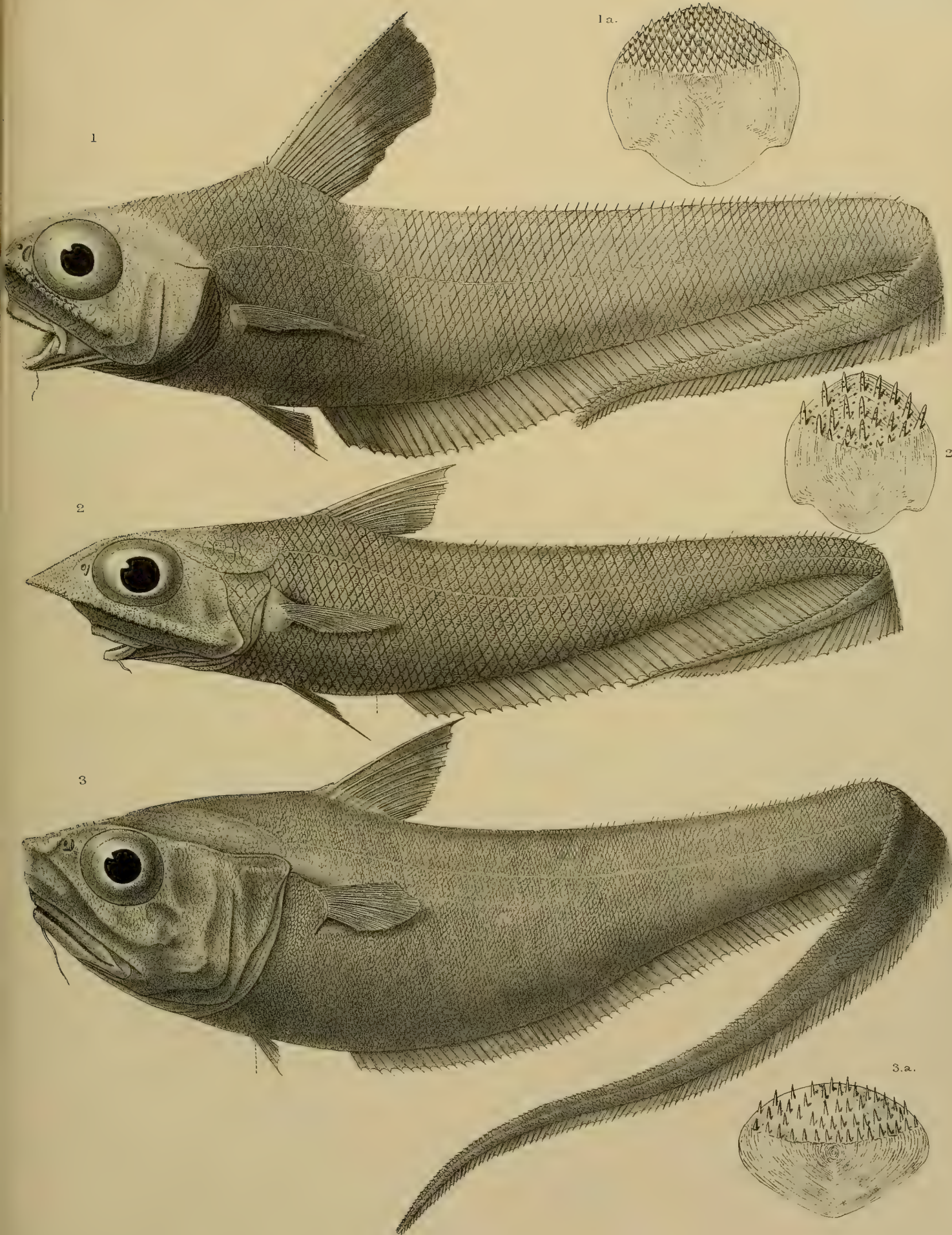
PLATE XL.

SURVEY OF FISHING-GROUNDS, WEST COAST OF IRELAND, 1890-1891.

# EXPLANATION OF PLATE XL.

## Figure

1. *Macrurus æqualis*, Günther (p. 463).
- 1a. Scale of same, the spinelets shorter and more conical than is the case in scales from young examples.
2. *Macrurus calorhynchus*, Risso (p. 451).
- 2a. Scale of same, adult condition.
3. *Macrurus lævis*, Lowe (p. 472).
- 3a. Scale of same, adult condition.



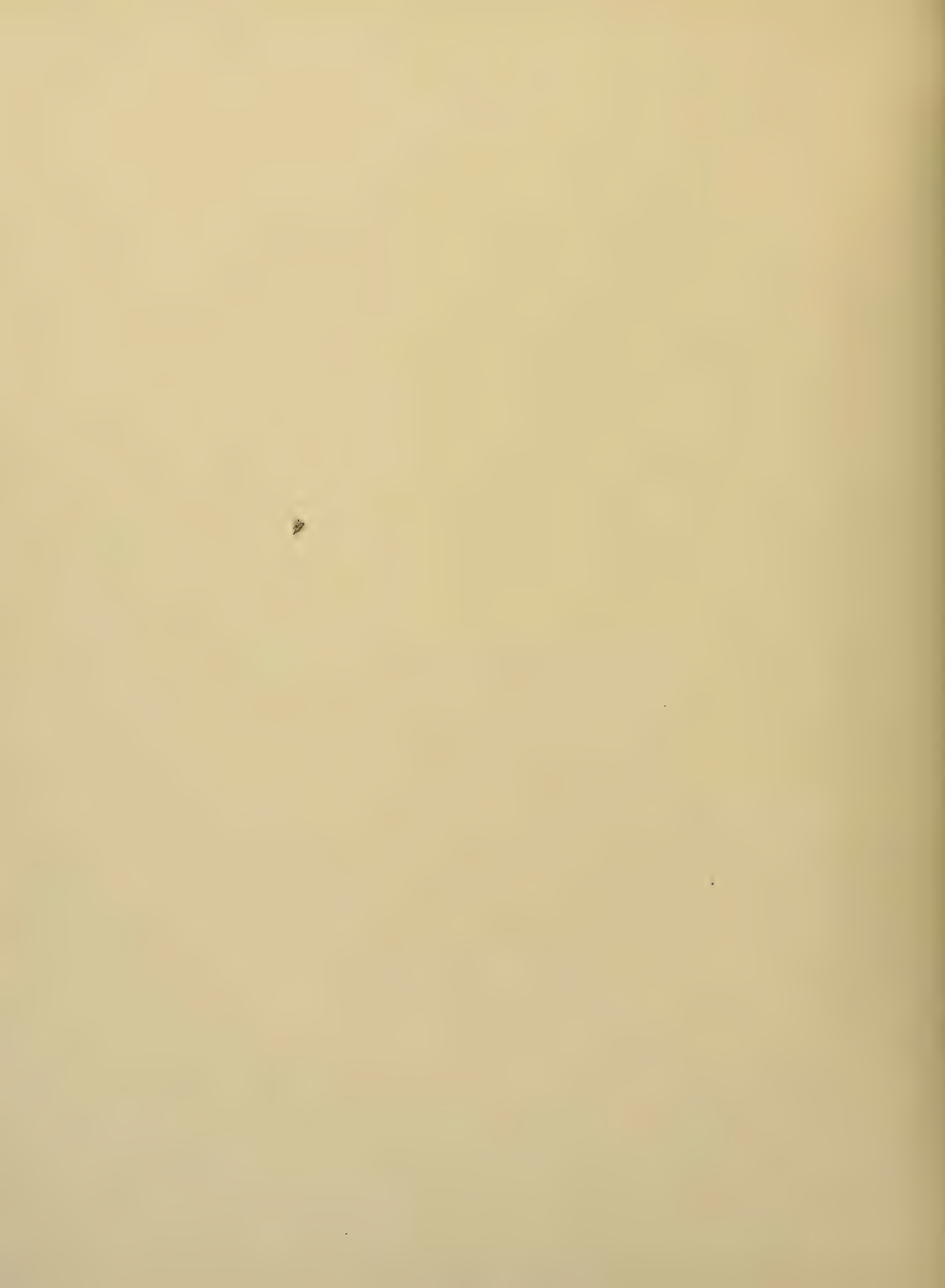


PLATE XLI.

SURVEY OF FISHING-GROUNDS, WEST COAST OF IRELAND, 1890-1891.

# EXPLANATION OF PLATE XLI.

## Figure

1. *Gadus argenteus*, Guichenot (p. 434).

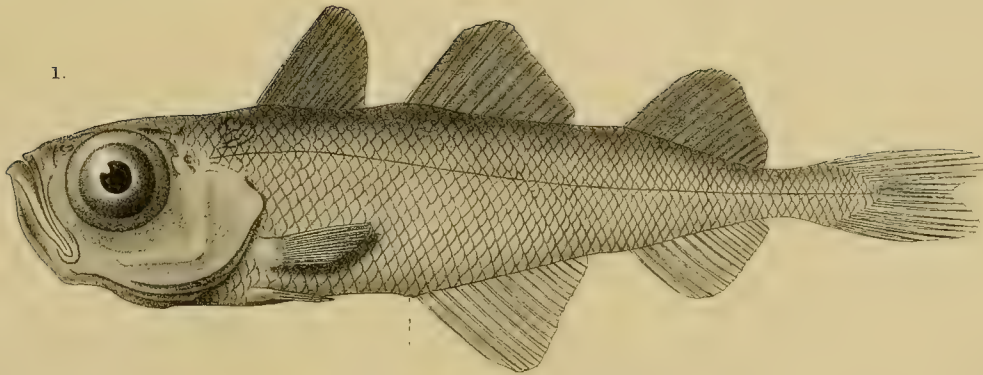
1a. View of the superior surface of an adult head, showing the arrangement of the muciferous cavities: *m. c.*

2. *Nettophichthys retropinnatus*, Holt (p. 511).

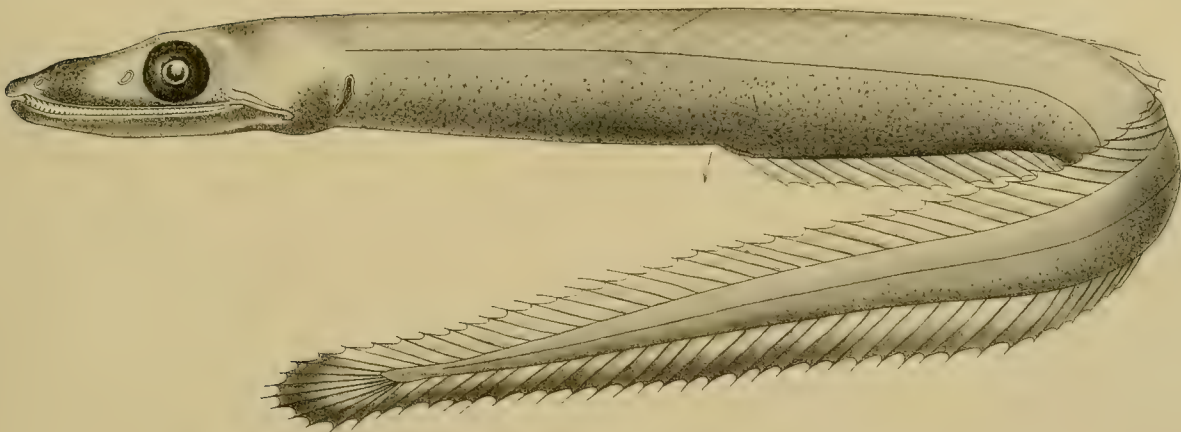
Type specimen.

3. *Gobius Friesii*, Malm. (p. 417).

1.



2.



3.

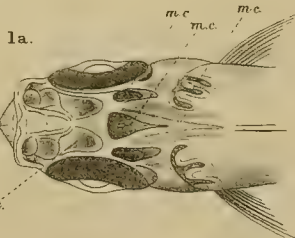
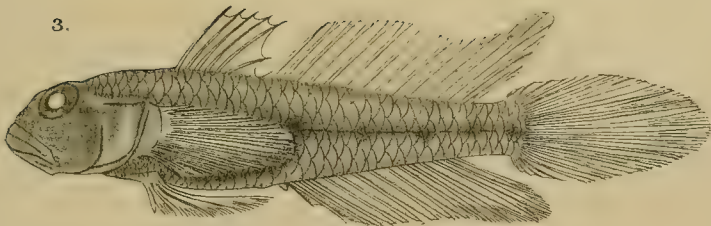




PLATE XLII.

SURVEY OF FISHING-GROUNDS, WEST COAST OF IRELAND, 1890-1891.

## EXPLANATION OF PLATE XLII.

### Figure

#### 1. *Scorpaena dactyloptera*, Delaroche (p. 409).

Adult example. The figure is in error, in that the rays of the lower portion of the pectoral fin are represented as being joined by membrane (a condition only found in young examples); and also in showing scales in the region of the suborbital ridge.

#### 2. Outline of the head of *Sebastes norvegicus*.

1*a* and 2*a*. Sections through the interorbital regions of *Scorpaena* (1*a*) and *Sebastes* (2*a*), showing difference of configuration.

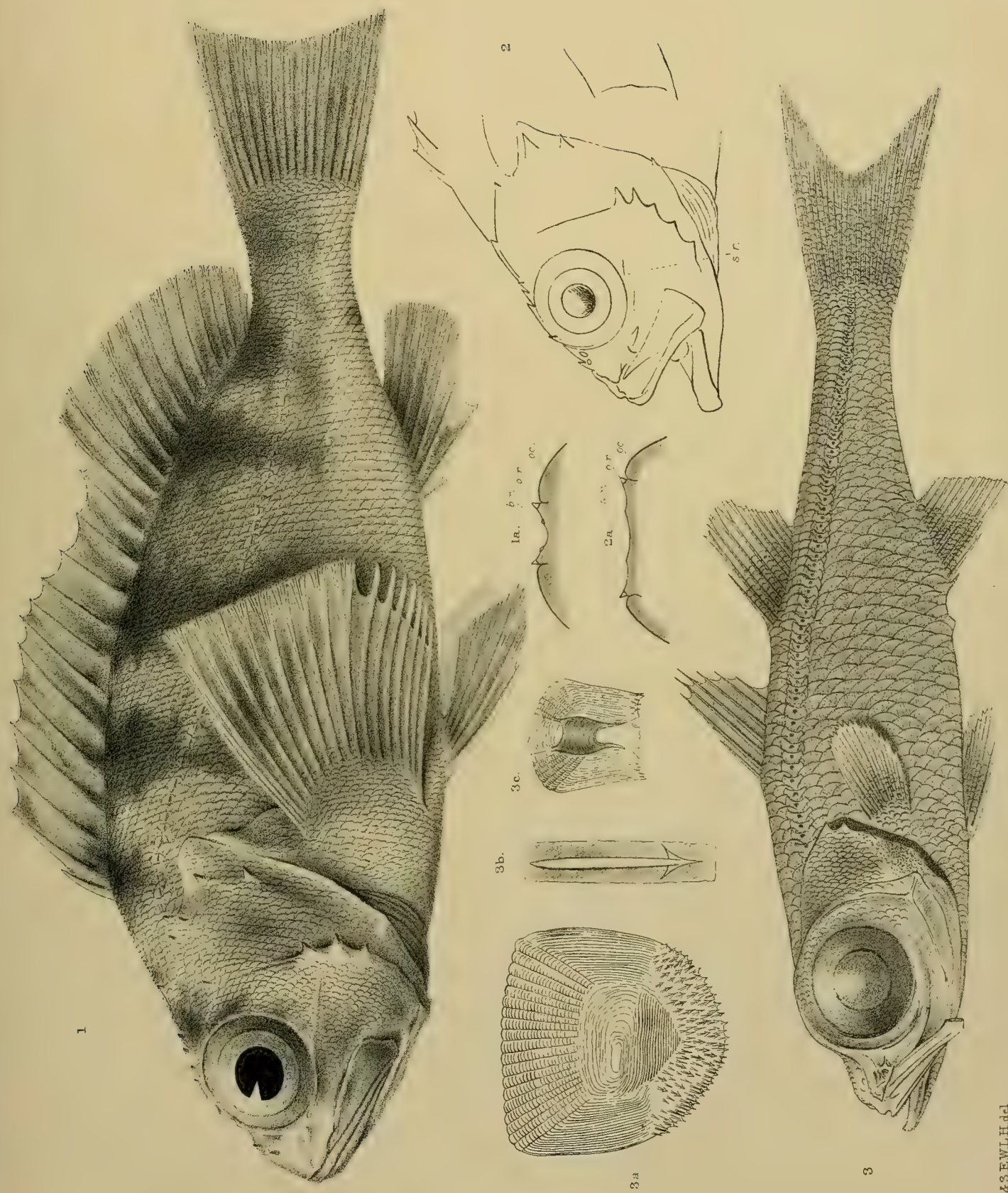
*b. r.* . . . bony ridges.  
*o. r.* . . . orbital ridges.  
*oc.* . . . eye.

#### 3. *Pomatomus telescopium*, Risso (p. 405).

3*a*. Typically ctenoid scale of same, from central region of body, showing spinous exposed surface.

3*b*. Spine of scale much magnified.

3*c*. Scale from lateral line.



Figs. 1a, 2 & 3. E. W. L. H. del.  
M. P. Parker lith.



PLATE XLIII.

SURVEY OF FISHING-GROUNDS, WEST COAST OF IRELAND, 1890-1891.

EXPLANATION OF PLATE XLIII.

Figure

1. *Centrophorus squamosus*, Gm. Linn. (p. 372).

1a. Lateral view of one of the pedunculate, keeled scales, taken from central region of body.

1b. Surface view of same, showing denticulate margins, and their variation.

2. *Macrurus rupestris*, Gunner (p. 455).

The anterior profile moderately oblique, and snout somewhat obtuse, as in ordinary type

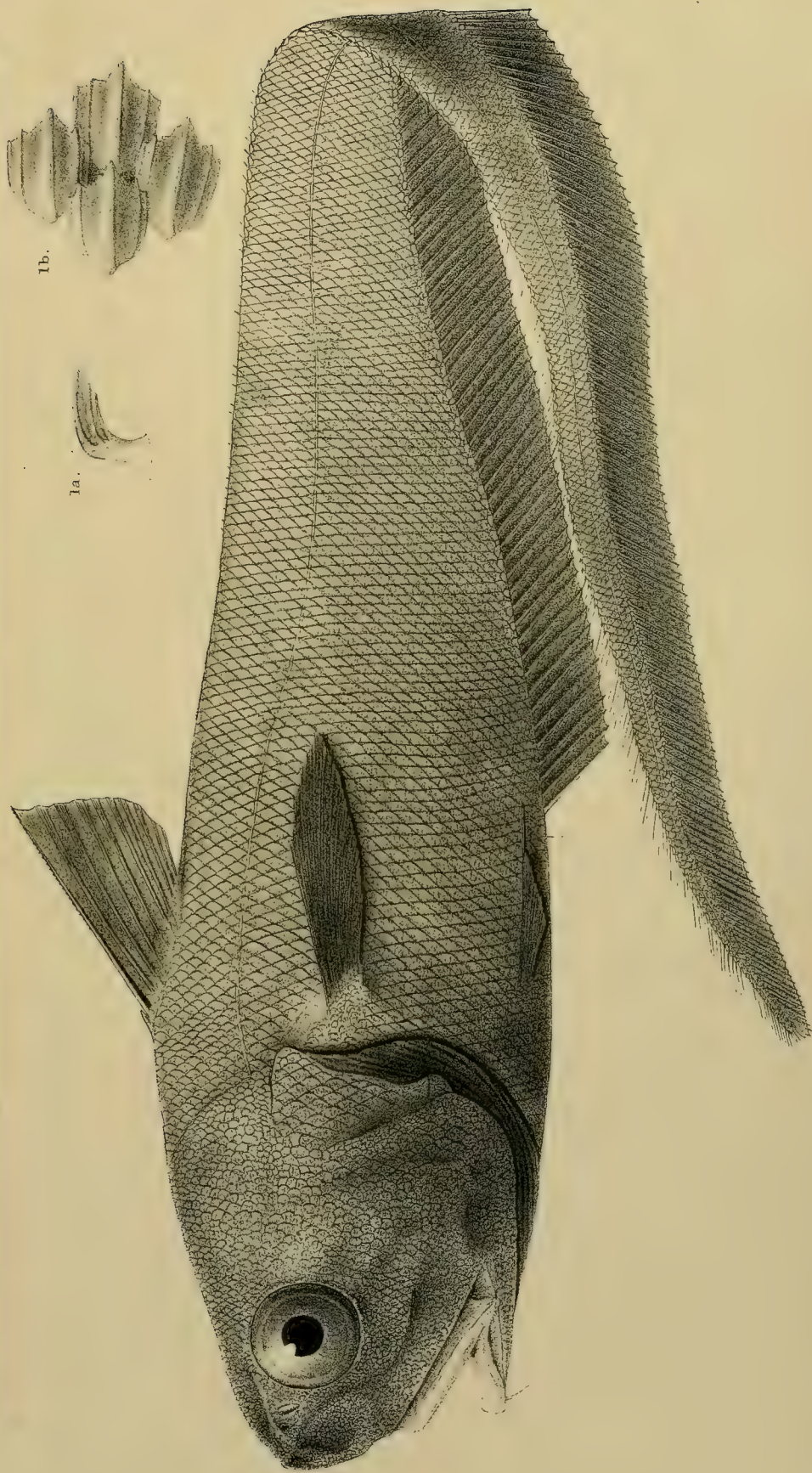




PLATE XLIV.

SURVEY OF FISHING-GROUNDS, WEST COAST OF IRELAND, 1890-1891.

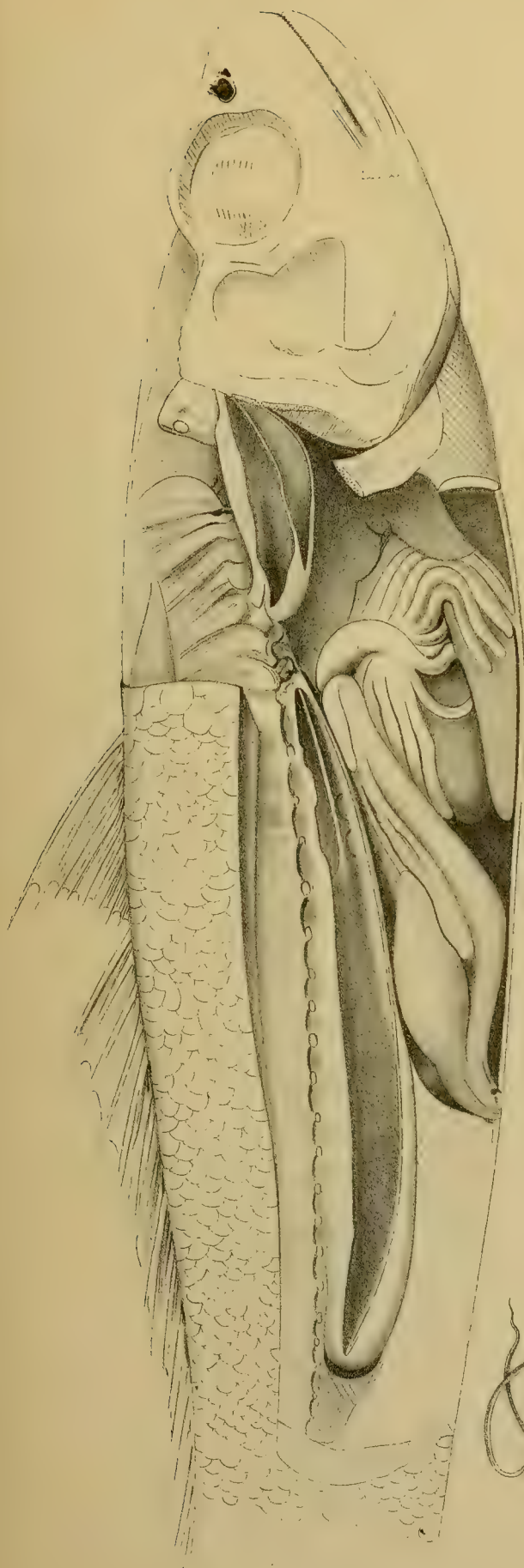
#### EXPLANATION OF PLATE XLIV.

*Mora mediterranea*, Risso (p. 436).

- A.* Dissection of the right side, to show the arrangement and extent of the swimming-bladder, in relation to the viscera and vertebral column.
- B.* Diagrammatic plan of the swimming-bladder, as seen from above.

Four egg-cases of *Batoidei* (pp. 392 *et seq.*)—

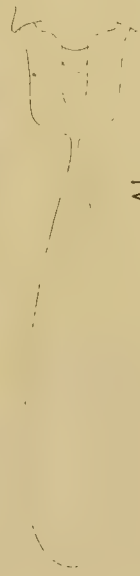
- I. of *Raia blanda*, 13·6 cm. × 7·6 cm. Parent fish measuring 46 inches in extreme breadth.
- II. of *Raia maculata*, 6·7 cm. × 4·3 cm. Parent fish measuring  $28\frac{1}{2}$  inches in extreme breadth.
- III. of *Raia circularis*, 6·3 cm. × 3·3 cm.
- IV. of *Raia microcellata*, 9–10 cm. × 5·7 cm. Parent fish 34 inches in extreme length, and  $23\frac{3}{4}$  inches across the disc.



A



A'



IV

III

II

I





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PLATES XLV. TO XLIX.

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(PLATES XLV.-XLIX.)

[Read APRIL 24, 1895.]

[COMMUNICATED BY PROF. D. J. CUNNINGHAM, M.D., F.R.S., HON. SEC., ROYAL DUBLIN SOCIETY.]

### Introduction.

AT a time when I was endeavouring to obtain information regarding the relative cutaneous sensibility of the hands and feet of apes and men by a microscopic examination of the skin, Professor Cunningham of Trinity College, Dublin, suggested to me that I should investigate the arrangement of the papillary ridges on the hands and feet of monkeys generally, in the hope that thereby I might be able to throw light upon any fundamental or ground plan which may determine the particular *patterns* which Galton,\* in his treatise on "Finger-Prints," has shown that these papillary ridges assume in the human fingers.

Notwithstanding the great variety in the designs of the patterns among human finger-prints, Galton demonstrates that they may be classified under a small number of primary forms. It seemed probable, therefore, that among monkeys the primary forms of the patterns of human finger-prints might be found in conditions sufficiently simple to afford a key to the production of the more elaborate human patterns. With this end in view, I prepared a considerable number of impressions from the hands and feet of living Primates.

### Methods.

The method adopted in securing these impressions was that employed in the Anthropological Laboratory in Trinity College, Dublin. It consists in applying the hand or foot to a plate of glass covered by a thin film of printers' ink, evenly distributed, as well as rendered of uniform consistence by means of

\* Galton, "Finger Prints," 1892.

a gelatine roller. After a few seconds of steady pressure upon this prepared plate, the hand or foot was removed as carefully as possible. As there was a constant tendency to blur the impression while withdrawing the limb, a *dab* impression of the flexor aspect of each digit was taken on the same plate which contained the imprint of the palm or sole.

All the monkeys were thrown into a state of extreme terror by being caught and removed from their cage, even by their keeper; and in order to obtain the impressions it was necessary to conceal each animal in a bag, from which a hand or foot was protruded as required. Still they all, more or less, resented the contact of their skin with the sticky plate of glass, and in consequence clear impressions were extremely difficult to obtain. I also endeavoured to obtain impressions by blackening the hand and foot with printers' ink, and then applying them direct to paper, but a satisfactory impression was only secured now and then by this means, while the general result was not nearly so good as by the first method. In the case of a male chimpanzee I succeeded in obtaining dab impressions of his right index and medius digits on paper, having previously blackened his hand; but, unfortunately, this made him so suspicious that he absolutely refused all further assistance, and defied every attempt to secure his hand and foot-prints either by cajolery or by force. With this exception, in the manner indicated, I secured impressions of the hand and foot of the following Primates in the monkey-house of the Dublin Zoological Gardens, viz:—

*Ateles ater* (the black-faced spider-monkey).

*Cynocephalus babouin* (the yellow, or dog-faced, baboon).

*Cercopithecus niger* (the black ape).

*Cercocebus fuliginosus* (the sooty mangabey).

*Macacus cynomologus* (the egret monkey).

*Cynocephalus mormon* (the mandrill).

My best thanks are due to Dr. Browne, of Trinity College Anthropometric Laboratory, for his kind assistance in the tedious work of preparing the impressions.

I cannot sufficiently express my indebtedness to Professor Cunningham, not only for many valuable suggestions during the preparation of this Paper, but also for having obtained for me the permission of the Council of the Royal Zoological Society of Ireland to make the necessary impressions.

It was some time before the glass plates were sufficiently dry to permit of their being freely handled; but when this could be done with safety, each plate was used for the production of a photographic print, in which the original impression was magnified eight diameters. This scale was sufficiently distinct for the examination and interpretation of the designs.

Galton, in his work on "Finger-Prints," already referred to, suggests that the papillary ridges may be of use in raising the mouths of sweat-ducts, and in assisting the sense of touch. Even if both of these suggestions be accepted, it is not clear why, in certain places, the ridges should assume the form of definite designs. It is true that the touch-bodies which are located in the papillary ridges are very numerous, both in the palm of the hand and sole of the foot; nevertheless, touch-bodies are fairly plentiful in many other regions of the skin which are not associated with papillary ridges, arranged in patterns. Indeed, if we compare the sole of man's foot with the palm of his hand as regards sensibility, we shall find\* that the sole is much less sensitive than the palm, although in both the papillary ridges are equally numerous and distinct. Again, such regions as the tip of the nose, the red part of the lips, and the dorsum of the third phalanges, are from two to three times as sensitive as the plantar surface of the great toe, and yet the former regions are not distinguished by papillary ridges, whereas the latter is so characterized. Further, as regards the palm itself, Kollmann† states that touch-bodies are most numerous on the tips of the fingers; somewhat diminished in numbers on the three eminences on the palm which lie above the clefts between the fingers; then still more reduced in numbers on the ball of the thumb and ball of the little finger; and, finally, much less numerous on other parts of the palm. Now, it is necessary to note two points in connexion with this statement—*First*, that the papillary ridges do not dwindle either in numbers or in distinctness, although the touch-bodies become reduced in numbers; and *second*, in each of the areas to which Kollmann directs special attention, viz. the tips of the digits and the various palmar eminences, the papillary ridges are so arranged as to form patterns or designs. It seems to me, therefore, that in certain regions great sensibility may be associated with the presence of papillary ridges, but that we cannot assume that the presence of papillary ridges is synonymous with increased sensibility. Of course I fully recognize the fact that the greater sensibility of such an area as the tip of the nose may be accounted for by a thinner cuticular covering; but this only shows that acute sensibility is not dependent on papillary ridges. Again, Professor Cunningham has reminded me that papillary ridges, like any papillary surface, have "a kind of frictional sensibility—a discriminating power—a capability of distinguishing the texture and quality of another surface over which they may be rubbed." But while granting this discriminating sensibility, and recognizing its value to an ape swinging from branch to branch, as well as the perfection to which it may attain by training, as in the hand of a blind man, yet I do not think that it accounts for the arrangement of the papillary ridges and the production of definite patterns.

\* Textbook of Human Physiology. Landois and Stirling, 1886, vol. 2.

† Kollmann, quoted by Landois and Stirling. *Ibid.*, p. 1153.

Apart from any question of the functions of papillary ridges, Kollmann\* conceives them to be formed through lateral pressure between nascent structures. Still such a mode of growth will not explain the formation of the patterns.

Attention has also been drawn to finger-prints of monkeys by Allix,† who gives an elaborate series of illustrations along with his Memoir. I have examined these figures under a large magnifying-glass, and they convey the impression that they are interpretations rather than drawings, and consequently their value as absolute reproductions of monkey finger-prints is diminished.

*Sweat-Glands*—A consideration of papillary ridges would be incomplete, if no notice were taken of the associated sweat-glands: and that for two reasons—first, because of the great number of sweat-glands in those regions where papillary ridges are found; and second, because of the association of the mouths of the sweat-ducts with the summits of the papillary ridges. Sweat-glands attain their numerical maximum in the palm of the hand, and they are not materially reduced in numbers in the sole of the foot. Making due allowance for the fact that sweat-glands are always most numerous in regions devoid of hairs, and for the further fact that a moist surface increases the acuteness of the sense of touch, I am of opinion that these reasons do not fully account for their great numbers in the sole of the foot, where the acuteness of the sense of touch is considerably less pronounced than in the hand. Again, there must be some definite reason for the constant opening of the sweat-ducts on the summit of the ridges, instead of in the intervening furrows. It seems a fair assumption that their point of opening is that which is best suited for the expression of the secretion during such an act as that of grasping; whereas, if the orifices had been situated in the furrows between the ridges, the same act would have led to the compression and closure of the orifices of the sweat-ducts.

As the result of careful scrutiny of the monkey impressions in my possession, I may state that the papillary ridges are remarkably distinct, and the intervening furrows very pronounced, notwithstanding the small size of the hands and feet of the animals in question. Now, while prominent papillary ridges are no doubt of much value in connection with the sense of touch, whether as providing for increased sensibility for surfaces thickly covered by epidermis, or as endowing the palm and sole with a frictional sensibility of a discriminating kind, I am of opinion that these explanations do not exhaust the possible functions performed by papillary ridges, any more than they account for the direction of the ridges or their arrangement in the form of patterns.

Certain monkeys and opossums possess prehensile tails, the ventral surfaces of

\* Kollmann. *Der Testapparat der Hand der menschlichen Rassen und der Affen.* Quoted by Galton, 9. v.

† Allix. *Ann. Sc. Nat.*, 5th series, vol. ix., 1868.

which are provided with papillary ridges; and while admitting that an increased degree of sensibility is of much importance in connection with a prehensile organ, I do not see that we thereby account for the fact that such prehensile tails have the papillary ridges arranged *transversely*. A smooth moist surface would undoubtedly be much better adapted for grasping; but it would be extremely difficult for such a surface to suddenly release its hold; and, moreover, it would lose the discriminating sensibility of the papillary surface.

It seems to me that the *direction* and the *arrangement* of the papillary ridges are intimately associated with the act of grasping. Although they are comparatively very low ridges, yet they must cause a certain amount of friction, and thereby prevent slipping, while the naturally moist and clammy condition of the palm and sole of monkeys must be of material assistance to the firmness of the grasp. A man instinctively moistens the palms of his hands when he wishes to make his grasp more secure; and the grasping power of monkeys must be considerably increased by the application of numerous moist papillary ridges which are capable of intimate adaptation to the surface of the object grasped.

Attention may now be more closely directed to certain distinct and practically constant eminences on the flexor aspects both of the hand and foot of monkeys and men. In the hand these eminences are situated as follows:—

- 1st. Opposite each phalanx, but especially the terminal phalanx, where each eminence develops in the form of a rounded pad.
- 2nd. Three eminences situated in the palm above the clefts between the digits.
- 3rd. The thenar and hypothenar eminences.

Similarly, in a monkey's foot corresponding eminences are found, the thenar eminence being situated on the inner border of the foot, while the hypothenar eminence has its place taken by the heel. Before discussing the significance of these eminences, I would direct special attention to drawings of the hands and feet of such animals as the Phalanger and *Didelphys virginiana*, by Allix,\* who figures eminences covered by papillary ridges in a series of areas exactly similar to those mentioned above, while the remainder of the hand or foot is represented as quite scaly.

In seeking an explanation of this series of eminences, we might claim that, in the case of the hand, the muscles of the thumb and little finger, and in the case of the foot, the muscles of the great and little toes, are respectively responsible for the upheaval of corresponding elevations. No doubt they do act in this way to a

\* *Loc. cit.*

certain extent, but in monkeys these muscular groups are comparatively feeble; and, moreover, muscular growth will not account for the remaining eminences. It may be urged that the terminal phalanges are bulbous in response to the corresponding delicacy of their sense of touch; but this claim cannot be made on behalf of the other eminences in the hand or foot.

The three eminences situated in relation to the bases of the digits can scarcely be accounted for by lateral pressure between growing structures, since the digits merely develop as bud-like outgrowths from the free end of a limb, which at first is in reality only a larger bud.

I am thus led to conclude that all these eminences are special developments which begin to make their appearance whenever an animal, in the process of its evolution, commences to use its hands and feet for purposes of prehension associated with locomotion, and that the papillary ridges which cover the eminences assist these functions after the manner of the papillary ridges which cover the palm and sole generally.

Upon the theory so expressed it would naturally follow that the arrangement of the papillary ridges in the palm and sole must be determined by the *shape of the eminences* and the nature of the intermediate areas. That this is so, is, I believe, entirely borne out by an examination of the monkey impressions. It is certainly a most remarkable fact that the designs or patterns are practically entirely confined to the positions occupied by the various eminences, while in the intermediate areas the papillary ridges are either arranged transversely to the long axis of the digit or member, or with such slight modification of this direction as would place them parallel to the long axis of any cylindrical object which might be grasped by the hand or foot.

An examination of the hand of *Ateles ater*—the spider-monkey—in which the pollex is wanting, shows that the papillary ridges deviate, only to a slight extent, from the longitudinal direction even in those areas where we expect to find eminences presenting characteristic designs. I regard this disposition of the papillary ridges as directly associated with the modification in the grasping power of the palm due to the absence of the pollex. Professor Cunningham has kindly supplemented my series of impressions by a few of the hand and foot of the orang-utan. The hand of this important anthropoid, whose habits are largely arboreal, is also noteworthy for its small and rudimentary pollex. In this case the papillary ridges over the greater part of the palm are remarkable for their general longitudinal direction, and a similar direction prevails over the palmar eminences with the exception of that corresponding to the ball of the rudimentary thumb.

Apart from the hook-like manner in which both the orang-utan and the spider monkey use their hands in performing trapeze-like movements, there can be no

doubt that their palms are capable of considerable *lateral* folding, as is clearly indicated by the pronounced longitudinal skin creases which their palms show, and I believe that it is in this latter class of movements that the palmar papillary ridges provide increased security for the grasp. The hands bring primarily grasping organs which perform their functions in virtue of different degrees of the power of bringing the opposing muscles into play, purely transverse papillary ridges are scarcely to be found except on the palmar surfaces of the second phalanges. In the palm itself, transverse ridges are scarcely to be seen, although a small number of ridges less oblique than elsewhere, are to be found in some cases immediately on the proximal side of the eminences opposite the inter-phalangeal clefts. Again, where the grasping power of the pollex is feeble, and the movements of the palm supply the deficiencies of this digit, ridges may be seen occupying the centre of the palm, and running in its long axis from the interval between the thenar and hypothenar eminences towards the roots of the fingers, as in the hand of the sooty mangabey.

In considering the arrangement of the papillary ridges in the sole of the foot, it is necessary to bear in mind that in primates this organ plays an important part in prehension, as well as in supporting the weight of the animal. The hallux is situated on the inner border of the foot at a varying distance from the heel, and its position influences the disposition of the papillary ridges. In this way we may recognise two areas in the sole of the foot, one situated between the hallux and the heel, and the other between the hallux and the roots of the toes. In the hinder area, which we may regard as principally associated with support, the papillary ridges practically run transversely, as may be seen by reference to feet of the spider-monkey, the dog-faced baboon (Pl. XLV.), and the orang. If either of these creatures were standing upon a cylindrical object, like the branch of a tree, with the feet transverse to its long axis, and without bringing the grasping power of the hallux into operation, these transverse ridges would be parallel to the long axis of the branch, *i.e.* in the most favourable position for assisting in maintaining the hold.

In the feet of the mandrill (Pl. XLVI.)—or of the black ape (Pl. XLVII.)—the same condition may be noted, but in them the hallux is situated further back, and the heel is thereby somewhat cleft or double, hence the prehensile power of the sole is brought nearer to the heel, and, consequently, there is an obliquity introduced into the direction of the papillary ridges, which at once shows that the position they would assume in the act of grasping a cylindrical object would be one more or less parallel to the long axis of the object grasped. The same fact is emphasized in the foot of the orang-utan, *viz.* the distinct obliquity of the papillary ridges in the grasping area, in addition to their general transverse direction in the more especially supporting area.

In coming to the consideration of the eminences in the palm and sole, and the arrangement of the papillary ridges upon them, I am of opinion that the production of any special "design" or "pattern" is to some extent an accidental occurrence. In other words, the pattern is dependent upon such conditions as—the particular shape assumed by each particular eminence, its rate of growth, and any defects to which it may be liable—conditions which must be subject to considerable variation, especially as we pass from monkeys whose grasping power is practically essential to their safety, to man whose means of security and flight from danger do not depend upon the grasping power of his hands and feet. Consequently, I find among those which have come under my notice, that although the monkey patterns are undoubtedly simpler and of less varied designs than the patterns found in man, there is nevertheless a considerable amount of variety even among them.

Assuming that the shape and size of the eminences influence the pattern constructed by the growth of the papillary ridges, it follows that the most freely developed eminences will show the simplest forms of design, while, at the same time, the nature of the design would be such as should assist the grasping power by providing a surface capable of easy adaptation to the object grasped, and one not likely to be readily displaced so long as pressure was maintained. Now, the simplest form of eminence is one with a circular base and a free surface rising very gradually to a flattened dome-like summit. As such a projection grew, the papillary ridges would naturally tend to arrange themselves in a series of more or less complete concentric circles, increasing in diameter from the centre or summit of the eminence—which would be occupied by an extremely short papillary ridge—practically a blunt point—or by a corresponding depression, until at the base the concentric lines would be interfered with by ridges running in other directions, and associated either with those of other eminences, or of those intermediate areas already described. That such an arrangement does actually occur may be seen by reference to Pl. XLVIII., in which the thenar eminence and the eminence near the root of the little finger present marked instances of the concentric arrangement of papillary ridges around one or two short central rod-like ridges. Additional examples of this arrangement were seen in the hands of the Egret monkey.

The simplest modification of this fundamental pattern is seen on the three eminences at the bases of the digits of the dog-faced baboon (Pl. XLIX.), in the mandrill, and in Plate XLV., in all of which the large size and the flattened summits of the eminences lead to a corresponding increase in the development of the core, the result being the production of several short, almost longitudinal ridges, bordered by a series of widening ellipses until the concentric circles are finally produced.

The eminence in the hypthenar region of the mandrill showed two features worthy of interest; first, the transverse direction of the ridges constituting the core of the design, and, second, the interference with the full development of the eminence on its ulnar or free border, resulting in the production of a series of pyriform loops. Similar pyriform loops may be seen on the eminences at the bases of the digits in Pl. XLVII.

On the thenar eminences, an interesting series of patterns was found. These varied from simple, almost perfectly concentric ridges surrounding a short central one, as in Pl. XLVIII., to a series of pyriform loops in the left hand of the same animal, and an attempt to form two foci, as in Pl. XLIX., which has only resulted in the production of two sets of pyriform loops dovetailing into each other.

The discussion of the papillary ridges on the palmar aspects of the digits will be undertaken most satisfactorily by considering the phalanges separately.

The *first* phalanx of each finger possesses a modified bulging eminence, and the arrangement of its papillary ridges varies accordingly. The *second* phalanges present the ridges in their simplest form, and on them the direction is mainly transverse to the long axis of the digit, *i. e.* parallel to the long axis of any object grasped in the hook-like manner characteristic of trapeze-movements (Pls. XLVI. and XLIX.).

On the first phalanges, the eminences are not so fully developed as those of the palm and sole, and consequently the ridges present forms which are intermediate between a transverse and a concentric arrangement.

*The terminal or ungual phalanges* of all the digits possess marked bulbous eminences on their palmar aspects, and on them the papillary ridges are modified to correspond. The consideration of this group of ridges derives additional interest from the fact, that, in man, the corresponding regions have been specially studied, in whom, moreover, the patterns have been shown to be so persistent as to afford a reliable basis for establishing individual identity.

It is well to note that the conditions provided by the terminal phalanges differ considerably from those prevailing in the regions of the palm or sole, where we have already seen patterns located. In the first place, eminences in the palm or sole are elevated areas rising out of a general flattened surface. Their growth and expansion may be restricted by the presence of neighbouring similar elevations, whereas the terminal phalanges are free at their extremities as well as on two borders. The only restriction to the growth of papillary ridges is found at their proximal end, where the abrupt flexures of the terminal articulations occur. In the second place, the development of a nail upon the dorsal aspect of each terminal phalanx is, undoubtedly, an important factor in producing the elongated character of the terminal phalanx, whose length is always greater than its osseous element would lead us to expect. This series of conditions must also act as modifying

influences in determining the shape and dimensions of the bulbous projecting eminence, or pad, which characterises the palmar aspect of a terminal phalanx.

An examination of the papillary ridges covering the palmar aspect of a terminal phalanx, therefore, resolves itself into two parts; first, the arrangement of the ridges where there is no raised area, and second, their arrangement where a raised area is present.

Where there is no raised area on the palmar aspect of a terminal phalanx there is no outstanding design or pattern, because, as already seen, this is always associated with raised areas or eminences, but, on the other hand, the papillary ridges are arranged transversely to the long axis of the phalanx. This is the condition of the ridges on the terminal phalanx of man on the proximal side of the *interspace* which encloses the pattern. On the distal side of the interspace the ridges are again arranged transversely, but with a convexity towards the convex-rounded free end of the phalanx to which they have adapted themselves. Of the monkey impressions in my possession the only one which gives a distinct indication of this arrangement is that of the right middle finger of the chimpanzee (fig. 1). Allix\* indicates this fact in one of his illustrations (pl. iii., figs. 2 and 4).



FIG 1.

The elevated area on the palmar aspect of the terminal phalanx presents a design or pattern corresponding to the shape of the elevation. The ridges on the proximal and distal aspects of the elevation are transverse. Of course around the convex free end of the phalanx the ridges become bent accordingly until along the lateral borders of the phalanx the ridges are almost longitudinal. This change in the direction of the ridges may be explained by the increase in the length as compared with the breadth of the phalanx and the coincident elevation of an area in the long axis of the digit.

It is not difficult to understand how the transverse ridges situated proximally might become separated from those characteristic transverse-convex ridges placed distally by the gradual projection of a raised area between the two sets of diverging transverse ridges so very distinctive of human patterns.

In none of my impressions from the lower monkeys are such interspace patterns visible, but in the two from the chimpanzee, showing the right index and medius, the interspace patterns are distinctly introduced (figs. 1 and 2), and they very closely resemble specimens of the looped designs figured by Galton. The apparent absence of interspace patterns among my monkey impressions may very probably be due to the



FIG 2.

\* *Loc. cit.*

circumstance that they are not rolled impressions, in other words the elevation occupying the interspace is, probably, so large that the boundary furrows have not been represented, and only a part of the large enclosed pattern is seen.

In comparing the lower monkey patterns with those of man the most noteworthy feature is the great simplicity of the former. Practically, all the patterns in my possession are modified loops, whose cores are represented by multiple rods running longitudinally. These patterns occupy a much larger area proportionately than in man, although some of them are suggestive of certain human impressions figured by Galton. In the chimpanzee a looped pattern is present in a distinct interspace. Instances of a pattern resembling a double-spiral are seen in the mandrill (Pl. XLVI.) and in the black ape (Pl. XLVII.), while in the orang-utan interspace patterns of the nature of loops and ellipses may be seen.

Thus, in the chimpanzee and orang-utan we find patterns similar to those commonly seen in man, whereas among lower monkeys the patterns approximate more closely to those found in the palm and sole, in which regions, as already explained, the shape and immediate surroundings of the eminences determine the nature of the pattern assumed by the papillary ridges which cover them.

Finally, in the higher apes and in man the patterns become more restricted in size and complex in outline because of the more circumscribed nature of the elevated area they cover, and for the same reason they are readily presented in an interspace enclosed by the diverging transverse ridges, which, in their turn, have more scope for free development. No doubt the reduction in the size of the pattern-area on the terminal phalanges, which corresponds to a diminution in the size of an elevation, is directly associated with a change in the functions performed by the terminal phalanges as compared with those of the lower monkeys.

### Conclusions.

1. The papillary ridges and their intervening furrows are adjuncts to the prehensile function and power of the hands and feet *as well as* arrangements associated with increased sensibility and discrimination of the sense of touch.

2. The eminences on which papillary ridges form designs or patterns are specially developed areas raised above the general level of surrounding parts. They are also special developments in relation to the prehensile function. This accounts for their constancy in the hands and feet of animals which have these organs modified for prehension.

3. The "design" which covers each of these eminences has its character determined by the position, shape, and dimensions of the particular eminence.

### Postscriptum.

While this Paper was in the hands of the printer, I had an unexpected opportunity of examining the papillary ridges on the feet of a dead negro. The skin of the feet was extremely callous in some parts, and in consequence the impressions I obtained were somewhat imperfect, still they were sufficiently distinct to enable me to form a clear idea regarding the general arrangement and direction of the papillary ridges. From the point of the heel forwards to the ball of the great toe the ridges ran exclusively in a general transverse direction without forming any pattern. The ball of the great toe, on the other hand, presented a very distinct series of concentric ridges around a central whorl-like core. This pattern had developed much more freely towards the inner border of the foot than towards the centre of the sole, where the ridges ran in a more or less longitudinal direction. I could not make certain whether the ridges assumed the form of designs towards the outer border of the foot where the ridges ran obliquely outwards, but there was no indication of transverse lines across the sole at the level of the ball of the great toe. It appears, therefore, that the supporting area and the grasping area are clearly indicated on the feet in question.

Although the negro is regarded as belonging to a lower type of mankind than the European, yet very similar functions are performed by the feet of the two races, and, consequently, there is much interest attached to a comparison between impressions of the papillary ridges on the feet of the two races. My opportunity for such an examination has not been very extensive, but in all the cases I have studied there has been a distinct conformity so far as the presence of two characteristic areas are concerned, viz. a posterior area between the heel and the ball of the great toe, and an anterior area extending across the sole of the foot at the level of the ball of the great toe. In the former area the ridges have always been arranged in a transverse direction without the formation of patterns; in the latter, patterns are present, and between the patterns the ridges vary in their amount of obliquity. One pattern is situated on the ball of the great toe, another is situated opposite the cleft between the second and third toes, and another is found opposite the cleft between the third and fourth toes. I have not seen any pattern opposite the cleft between the great toe and the second toe, nor between the fourth and fifth toes. Their absence coincides with the absence of elevations in these regions, and would seem to be adverse to Kollmann's suggestion as to their causation, viz. lateral pressure between nascent structures.

With regard to the nature of the patterns found in the different feet under consideration, I think they are fully accounted for by the shape and size of the particular elevations on which they may be found. Further, the sub-division of the sole of the human foot into two areas, in each of which the papillary ridges possess a characteristic disposition, seems to me to be intimately associated with its evolution in its transition from an organ in which the prehensile function predominates, to one in which it principally serves the purposes of an organ of support.

### EXPLANATION OF PLATES.

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PLATE XLV.—Right foot of *Cynocephalus babouin* with toe impressions.

PLATE XLVI.—Left foot of *Cynocephalus mormon* with toe impressions.

PLATE XLVII.—Right foot of *Cercopithecus niger* with toe impressions.

PLATE XLVIII.—Right hand of *Cercopithecus niger* with finger-points.

PLATE XLIX.—Left hand of *Cynocephalus babouin* with finger-points.

NOTE.—In each case where imprints of terminal phalanges are shown, the first was always the thumb or great toe, according as it was hand or foot, and then the other digits were taken in order, so that the arrow shows the starting-point.























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## XI.

THE COURSE AND NATURE OF FERMENTATIVE CHANGES IN NATURAL AND POLLUTED WATERS, AND IN ARTIFICIAL SOLUTIONS, AS INDICATED BY THE COMPOSITION OF THE DISSOLVED GASES. (PARTS I., II., AND III.) BY W. E. ADENEY, Assoc. R. C. Sc. I., F. I. C., Curator and Ex-Examiner in Chemistry in the Royal University, Ireland.

[Read APRIL 24, 1895.]

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## Introduction.

It is, I believe, now generally accepted that the organic matters which, by one means or another, find their way into surface waters, are oxidised, and eventually reduced to simple substances by the operations of micro-organisms, and not by mere chemical changes independent of them. To these operations the term “fermentation” is usually applied.

This explanation rests chiefly on the results of bacteriological research, and especially upon the fact that the germs of these micro-organisms are present, practically, everywhere—in the air, in water, and in ordinary soil; and that they require but the necessary pabulum, such as refuse animal or vegetable matters, in a neutral or slightly alkaline medium, for rapid growth and multiplication.

The importance, from the chemists' point of view, of the recognition of the true agencies at work in setting up processes of oxidation in natural and polluted waters does not appear to have been sufficiently realized.

It suggests at once the possibility of classifying the organic matters to be met with in natural and polluted waters into two classes, viz. fermentable and non-fermentable, and of differentiating the one from the other when present in the same water.\*

We know that some of the organic matters found in natural waters either do not ferment at all, or do so with difficulty, such as peaty colouring matters and the organic matters found in good well and spring waters. Of a like character, also, are those which are found in sewage-water after they have undergone complete fermentation under aërobic conditions, such as obtain during slow filtration through sand or soil.

Amongst the fermentable matters may probably be included most, if not all, known organic substances, with the exception of antiseptics. Dr. Munro has shown, in his interesting and suggestive Paper on "The Formation and Destruction of Nitrates and Nitrites in Artificial Solutions and in River and Well Waters,"† that not only are such simple bodies as acetates and oxalates attacked by the organisms usually present in soil and water, but also such unlikely substances as ethylamine, cyanides, and thiocyanates, and he concludes that it would be difficult to make out a list of known organic compounds which are not fermentable under these conditions.

One of the most obvious results of the fermentation of small quantities of an organic substance in fully aërated water would, no doubt, be an absorption of the dissolved atmospheric oxygen therein, and an evolution of carbon dioxide; and if the water were preserved during fermentation under conditions, such that gases could neither escape from, nor gain access to it, these results would also be the most easily detected by chemical means.

A few tentative experiments carried out on the lines here suggested showed very distinctly that the above view was correct, and that even relatively minute

\* It is due to Dr. Dupré to make reference in connection with this point to a short Paper by him, entitled—"On Changes in Aëration of Water, as indicating the Nature of the Impurities present in it," and published in the Report of the Medical Officer to the Local Government Board, 1884.

† "Chem. Soc. Journ.," vol. 49, p. 677. See also p. 651.

quantities of fermentable matters, such as fresh sewage, when mixed with good river water, soon indicated their presence by causing an absorption of dissolved oxygen, and an evolution of carbon dioxide.

These experiments satisfied me that the consumption of oxygen and the formation of carbon dioxide, which must occur during the fermentation of small quantities of organic matters in a water, when taken together, provided a most delicate indication of the presence of such matters in a water.

But little consideration, however, was necessary to lead one to anticipate that a method of inquiry, based upon the determination of the changes in composition of the dissolved gases, would lead to much more definite results, especially when coupled with the determination of the inorganic nitrogenous products of the fermentation—such fermentation to be conducted under suitable conditions.

In explanation of my meaning, I would refer to the more recent researches on nitrification.

Dr. Munro,\* Dr. P. F. Frankland,† and Mr. Warrington,‡ have all demonstrated that the fermentation of ammonia to nitrous acid may occur in inorganic solutions to which no organic matters have been added. M. Winogradsky§ has extended these observations, and has not only shown that a nitrous fermentation proceeds when organic matters are rigorously excluded from the cultivating inorganic solutions, but he has also demonstrated that organic matters are formed from inorganic materials at the same time, the first step in their formation, possibly being, as suggested by him, the production of an amide from ammonium carbonate.

We find, moreover, abundant evidence given in Munro's Paper, that unfermented non-nitrogenous organic matter is positively prejudicial to nitrification, and that, if present with ammonium salts in a water containing soil or water organisms, they undergo fermentative changes before nitrification sets in.

We have evidence also from the same author's Paper that the nitrification by soil organisms of *nitrogenous* substances, with no added ammonium compounds, follows a similar course. A putrid bacterial fermentation first takes place, during which nearly the whole of the organic nitrogen is converted into ammonia, and this ammonia apparently only begins to undergo nitrification after the first fermentation of the organic matter originally present has been completed.

If, then, the nitrification, by the mixed organisms which ordinarily occur in soils and natural waters, of organic substances containing nitrogen, or mixtures of these containing no nitrogen with ammonium compounds, takes place in two distinct stages as above indicated, it is probable that accurate determinations of the more obvious products of each stage of fermentation, viz. carbonic

\* *Loc. cit.*, p. 653.      † "Phil. Trans.," 181, p. 107.      ‡ "Chem. Soc. Journ.," 59, p. 484.

§ "Annales de l'Institute Pasteur," vol. iv., pp. 213, 257, 760; vol. v., pp. 92, 577.

dioxide and possibly ammonia in the one; and of carbonic dioxide (if any be formed) and nitrous and nitric acids in the other, together with accurate determinations of the free oxygen consumed during both stages, would afford *data* for estimating the actual quantity of fermentable matters present in polluted water with sufficient accuracy for the purpose of water analysis.

Such a method of examination as here suggested promised results of a most definite character, and of especial value for the examination of polluted drainage waters, in that they would probably afford the means of accurately estimating the quantity of such water which could be safely allowed to drain into a river or stream of a given size, and would thereby lead to the possibility of formulating exact practical standards of impurity for drainage waters, which standards could be graduated according to local conditions of volume and flow of the stream.

The method of examination which I have sketched was, however, open to possible objections, which could only be answered one way or the other by a full experimental investigation. For instance, a water under examination would always contain mixed organisms, and the selective chemical functions of these might vary to such an extent that in no two experiments with the same water would similar values for the products formed, or oxygen consumed, be obtained. It might further be objected that a given result was due to the accidental presence of a particular organism.

There were, however, good reasons for believing that, if precautions were taken to experiment under certain conditions, as regards the relative quantities of fermentable matters, and of dissolved oxygen, the growth of similar sets of organisms, so far as chemical functions are concerned, would be encouraged, and that the products obtained thereby would be very similar in chemical characters.

The actual quantity of carbon dioxide, and no doubt of nitric acid, but probably to a more limited extent, formed relatively to the quantity of oxygen consumed during fermentation of similar volumes of different polluted waters, would no doubt vary with the composition of the organic matters originally present in them. But, for the purpose of water analysis, this would not affect the value of the quantity of oxygen consumed, as a quantitative index of the amount of the fermentable matters originally present, since this quantity would probably exactly represent that which a similar volume of the same water would require when discharged into a natural watercourse.

It must be remembered, too, that, by the complete fermentation under aërobic conditions of organic matters in an ordinary water, much the greater proportion of the organic carbon and organic and ammoniacal nitrogen undergo complete oxidation to carbon dioxide and nitric acid respectively, and only a very small proportion of either of these constituents remains fixed as fermented organic matters, and that variation in fermentative products due to selective chemical

action of the mixed organisms present would probably be shown most prominently in the last-mentioned products, viz. the fermented organic matters.

With these considerations in mind, I commenced a series of experiments as long back as the autumn of 1891. The slowness, however, of some of the fermentative processes under observation, combined with long-continued interruptions in the course of the work by other duties, has hitherto prevented my being in a position to publish any results. The scope of the investigation has also widened, and very many points have arisen and demanded experimental study, which were not anticipated at the commencement of the work. Even now, I cannot claim to have finished the investigation of many of these points.

My experiments, however, in so far as the original object of the investigation is concerned, have now reached a sufficiently advanced stage, I think, to render any further delay in publication undesirable. I therefore propose, in this communication, to deal with such experiments as bear directly on the question with which I started this investigation, viz. *whether the amount of the dissolved oxygen consumed during the complete fermentation of a polluted water might not be regarded, for the purpose of water analysis, as a quantitative index to the amount of fermentable substances originally present in it, provided that during the process care is taken to have the oxygen in excess in the water.* And, further, whether it might not be possible to separately estimate the volume of dissolved oxygen consumed during each of the two distinct stages in which it is supposed the nitrification of organic matter takes place. I say supposed advisedly, because it cannot be regarded as having been experimentally proved that the nitrification of nitrogenous organic substances, or of non-nitrogenous organic substances mixed with ammonium compounds, really takes place in two stages, except when the fermentation is carried on under partially aërobic and partially anaërobic conditions. There can be little doubt, for example, that in Munro's\* experiment on the nitrification of gelatin, in which, during the earlier stages of fermentation he noticed putrefactive products and the formation of ammonia, free oxygen must have been entirely absent from the lower layers of the solution he employed, judging from its strength.

It cannot be taken for granted, therefore, that the oxidation by fermentation of gelatin, or other nitrogenous substance, in the continued presence of an excess of free oxygen, would be "progressive," as above described, rather than "complete from the commencement."†

I may, however, anticipate in this particular, the experiments which I have to describe, and state that they all go to show that the fermentation of such bodies by the mixed organisms of soils and waters takes place in two perfectly distinct

\* *Loc. cit.*, p. 641.

† See Schützenberger on "Fermentation," p. 244. International Scientific Series, 1891.

stages, even in the continued presence of free oxygen, and that in the first stage the organic substance is simply broken down, the carbon and nitrogen, if present, being converted largely into carbon dioxide and ammonia, a small quantity of organic matter, however, remaining as such, but in an altered form; that in the second stage the ammonia is oxidized to nitrous or nitric acids, or both, and that, at the same time, the organic matters resulting from the first stage may be partially or completely oxidized, carbon dioxide and possibly nitric acid being formed;—also that the second stage does not commence until the completion of the first. I shall call these two “first” and “second” stages of fermentation for want of better terms; new terms are, in fact, wanted to describe them properly. My friend Dr. E. A. Letts has suggested to me a term which seems to be very suitable for the first, viz. bacteriolysis.

### Method of Experimenting.

In considering this question, three conditions which the method adopted would be required to fulfil had to be borne in mind:—

1. It should not be possible for any gas, during an experiment, to gain access to, or egress from, the vessel in which the experiment was to be carried on.

2. It should be possible to easily and accurately regulate the quantities of dissolved oxygen and of fermentable matters, relatively to one another in a liquid to be examined, so that the former should be in excess of the latter, or *vice versa*, just as required.

3. The external conditions of a liquid during fermentation should be similar in all respects, and such as to ensure, as far as practically possible, that every part of the liquid throughout its mass should be chemically similar at any interval of time during the continuation of the experiment.\*

These necessary conditions made it impossible for me to use the method of liquid cultivations, as commonly employed by bacteriologists, viz. nutrient liquid media, in which the relative quantities of fermentable matters and dissolved oxygen are not specially regulated, and which are kept in bottles or in flasks, which they only partially fill.

With such a method it would be quite possible, as bacteriologists have generally observed, to have a fermentation in the continued presence of an excess of atmo-

\* In connection with this point, see Dr. P. F. Frankland and Mr. Frew's very interesting experiments, described in their Paper on “A Pure Fermentation of Mannitol and Dulcitol.”—C. S. J., 61, p. 254.

spheric oxygen proceeding in the portions of the liquid immediately adjoining the surface exposed to the air in the vessel in which it was kept, and at the same time a fermentation in the practically complete absence of dissolved oxygen in the lower portions of the liquid. The only possible way of ensuring the third condition above stated, was to keep the water or liquid under observation in bottles completely filled and carefully closed with glass stoppers. The difficulties to be anticipated in practically carrying this out were those which would certainly arise with unavoidable alterations of the temperature of the liquid during the continuance of the experiment. With fall of temperature, there would be a tendency to draw air into the bottle, and with a rise there would be a tendency to expel a portion of the liquid from it, while with both rise and fall of temperature, there might be a disengagement, and possibly, in consequence, a loss of dissolved gases.

I found, however, that by keeping the bottles immersed, neck downwards, in distilled water, in large glass vessels which were covered with glass plates, and by exposing them to a temperature as equable as possible, that these difficulties could be overcome to such an extent that they could not give rise to errors sufficiently large to materially affect the results.

I shall again refer to this subject when dealing generally with the probable errors of the experimental results.

The foregoing consideration of the third necessary condition to be established in my method of experimenting has, it will be observed, included the first. There remains now for discussion the second condition.

For the purpose of this Paper it was of chief importance to observe the products of fermentation which had been carried on in the continued presence of an excess of oxygen relatively to the quantity of matter to be fermented.

It was also of importance to determine whether the complete fermentation, on the one hand, of the nitrogenous organic matters, and, on the other hand, of non-nitrogenous organic matters mixed with ammonium compounds, into carbon dioxide, water, and nitrous or nitric acids, in the continued presence of an excess of oxygen, was complete from the commencement or was progressive.

To effect these purposes, I adopted the general plan of commencing with strong solutions of sewage-waters, or of fresh peat, or of organic and inorganic substances of known strength and composition, in which the quantities of fermentable matters were in decided excess, relatively, to the quantity of dissolved atmospheric oxygen present, and then of making a series of gradually increasing dilutions with good tap-water, or, when necessary, with distilled water, such that the conditions should gradually become reversed, the dissolved oxygen in the higher dilutions becoming predominant in quantity. By this means I hoped to obtain results which would quantitatively indicate the changes resulting from the

fermentation of various fermentable matters under gradually varying condition from that in which the fermentable matters were in excess to that in which the dissolved oxygen was in excess.

One further general condition which had to be attended to in all the experiments need scarcely be mentioned: it was to make provision for keeping the liquids under observation in a slightly alkaline condition during fermentation. This was invariably done by adding, when necessary, very small quantities of pure dry sodium carbonate, which consisted partly of the normal carbonate and partly of the bicarbonate. When experimenting with sewage-water, it was found to be quite unnecessary to add any of this or other mineral substances. All the solutions were kept in the dark during fermentation.

### Apparatus Employed.

The bottles I have employed for preserving the waters or solutions under experiment, out of contact with air, have been made in two forms: one, the ordinary bottle-form with short necks; the other of flask form, with long, somewhat narrow necks. Both forms have been made of stout glass with very carefully ground stoppers. The capacity of the bottles has varied, according to circumstances, from about 300 c.cs. to 2500 c.cs.

As before stated, the bottles, when filled, were carefully stoppered so as to leave not a trace of air bubble in them. To avoid the possibility of small quantities of air passing into them between the neck and the stopper, they have been kept neck downwards immersed in distilled water. Under these circumstances, a little distilled water might be drawn into the bottles, or a little solution expelled from them, but not in sufficient quantity to introduce material error, provided the temperature of their contents was not allowed to vary much. When, from any cause, such as considerable variation of temperature, or the formation of gaseous products, other than carbon dioxide, during fermentation, disengagement of gas during the course of an experiment was to be anticipated, such gas would remain in the bottle, since this latter was kept neck downwards, and some liquid would be expelled from it between the neck and the stopper. It would be necessary, of course, to collect this gas, and separately measure and analyse it. To meet this special case, the flask-shaped bottles, with long narrow necks mentioned above, were employed. The neck of each bottle was graduated from the bottom of the stopper downwards, as follows: the bottle was completely filled with water, and the stopper firmly inserted; the stopper was then carefully taken out, and the height of the water was marked on the neck with a diamond as zero, the graduation was then proceeded with by withdrawing the water half a cubic centremetre at a time, and marking on the neck the height of the water as

each half c.c. was withdrawn. The neck being graduated in this way, it was possible to note immediately before displacing the disengaged gas, which was done over distilled water, the volume of water which would enter the flask and become mixed with its contents; the capacity of the flask, with the stopper inserted, and the composition of the gases dissolved in the distilled water being known, it was in this way possible to calculate and correct for the error which the admission of the distilled water into the flask would introduce in the estimation of the dissolved gases in the liquid under experiment.

The form of apparatus which I have used for extracting the dissolved gases, measuring and analysing them, is shown in the accompanying drawing. It consists of a mercury-pump combined with a gas analysis apparatus, and can be used for all three operations required in the examination of the gases dissolved in liquids, viz. for their extraction, measurement, and complete analysis. The remaining parts of the apparatus which are shown in the sketch consists of a Liebig's condenser of glass, and a round-bottomed stout glass flask with a side tube from the neck.\*

The flask, which for convenience of reference I propose to name the laboratory flask, is made of sufficiently stout glass to bear a vacuum. The only points of importance, so far as shape is concerned, are that it must be round-bottomed, and that the neck must be somewhat long and tapering to allow of the short india-rubber cork, by which the inner tube of the condenser is packed air-tight into it, fitting sufficiently deep down to leave a space above itself for a water or mercury luting.

The capacity of the flask should be about four times the volume of liquid to be boiled in it. It is convenient to have two sizes, viz. 1500 c.cs., and 2500 c.cs.

The laboratory flask is employed for conducting the necessary operation of boiling the liquid under examination in vacuo, for the extraction of the gases dissolved in it. Since the condenser to which it is attached cools down, and condenses the aqueous vapour given off during the process of boiling, the liquid may be heated to violent ebullition continuously for any required length of time without fear of unduly raising the pressure of the vapour and gases in the flask.

The gas analysis apparatus proper, shown in the drawing, is an improved form of that which I have already described in a Paper, published in the "Scientific Proceedings of the Royal Dublin Society."† To that Paper I would

\* The glass parts of the apparatus were obtained from Messrs. Baird and Tatlock, of Glasgow and London.

† "On an Apparatus Applicable for Gas Analysis and Other Purposes."—*Scien. Proc. R. D. S.*, vol. vi., pt. ix., p. 555 (1890). Reprinted in the "*Chem. News*," 62, pp. 196-199, and 204-206.

refer for a more complete description of the principles of the apparatus and its applicability to other operations than that here described.

In this Paper I will only give a short description of the apparatus shown in the drawing, sufficient to explain the improvements which has been made on the older form, and to render intelligible the use of the apparatus for the purposes of this research.

Its essential parts are a gas burette and laboratory vessel, differing in many respects in form and use from those generally employed in other forms of gas-analysis apparatus, and a long pressure-tube provided at its upper end with a Friedrich's patent glass stopcock.

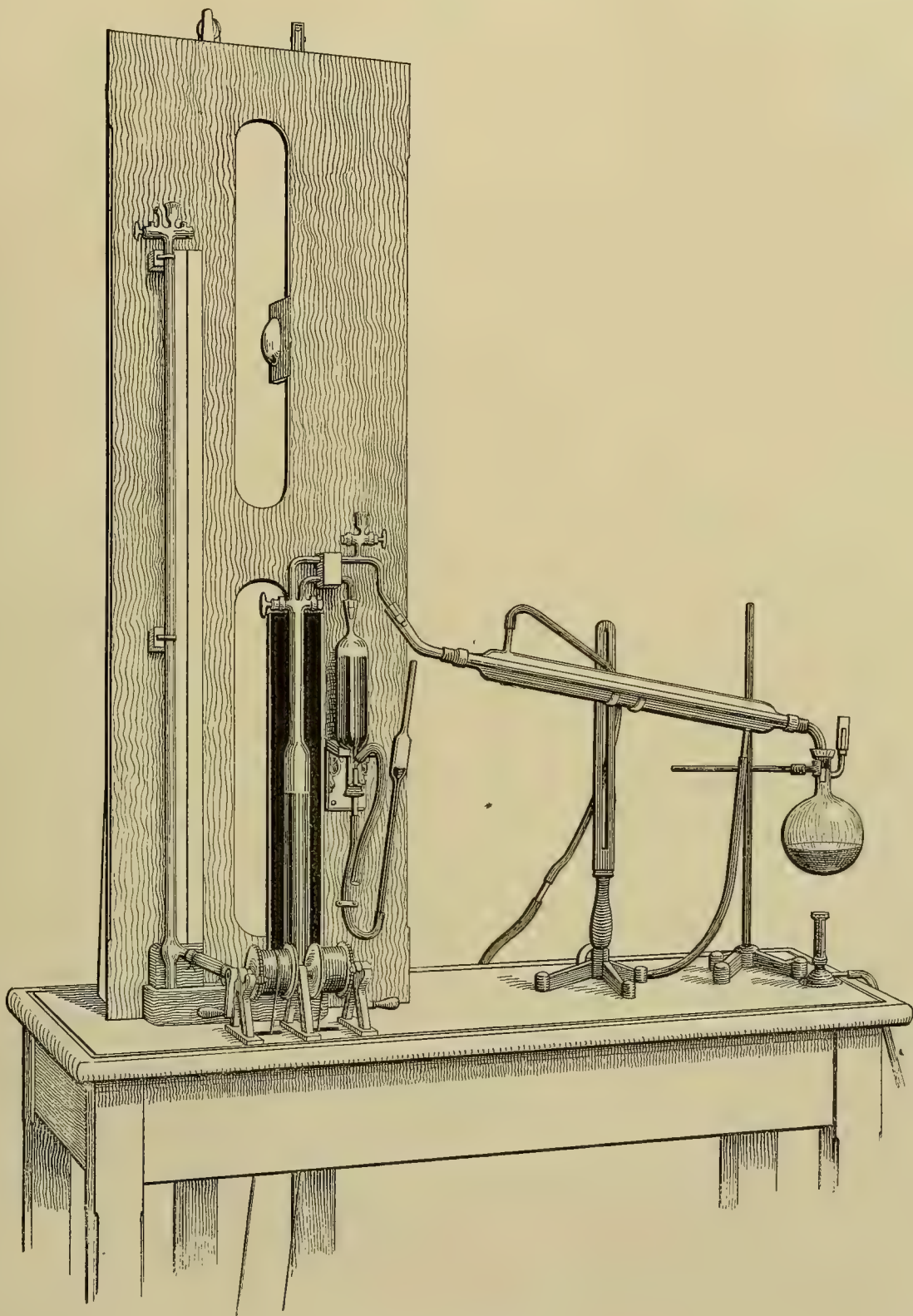
The form of the burette is exactly similar to that employed in my older apparatus. It is contracted at its lower end, and passed through a hole cut in the centre of the indiarubber bung which closes the lower end of the glass cylinder, enveloping the burette, and which thus provides a means of keeping the burette surrounded with a water-jacket. It is then bent at right angles, and joined to the pressure-tube by indiarubber tubing lined with canvas, and tightly wired to the glass tubes. The bottom of the cylinder, the joint and bent portions of the burette and pressure-tube sit in a trough cut out, and suitably shaped from a piece of solid mahogany, and which, during work, is kept filled with mercury to protect the indiarubber joint from the air.

The way in which the glass cylinder, burette and pressure-tube are supported is indicated in the drawing, but this will be more clearly understood from the drawing of the older form of the apparatus.

The supply of mercury to the burette and pressure-tube is regulated by means of a reservoir, which rests in a wooden box, suspended by a catgut line, and capable of moving freely from the top of the apparatus to the floor. It is prevented from swinging by a grooved guide fixed to the back of the apparatus, in the grooves of which slide corresponding portions of the box. The catgut line passes over the necessary lead pulleys to the windlass mentioned below.

The reservoir box can be raised or lowered by a small winch or windlass fixed in front of the apparatus, as shown in the drawing, and fixed at any point by the ratchet cut on one side of the winch drum. The flexible tube from the reservoir passes through a hole, cut in the wooden upright supporting the apparatus, at a point just below the level of the side branch from the pressure-tube, and is attached thereto.

It is essential that the flexible tube from the reservoir should be attached to the pressure-tube, and not directly to the burette, because, when the reservoir is kept for any length of time at a lower level than that of the bottom of the burette—and this is constantly necessary when employing the apparatus as a vacuum pump, or when measuring gases under very low pressure—there is a tendency



GAS-ANALYSIS APPARATUS.



for air to diffuse through the indiarubber tube. With this arrangement, if an appreciable quantity of air does thus diffuse during an experiment, it passes up into the pressure-tube when the reservoir is raised, and can be driven out when necessary through the stopcock at its upper extremity, without in any way affecting the experiment; as a precaution against the air being carried round into the burette by the inflowing mercury, the pressure-tube is expanded considerably where the side tube is attached to it, as shown in the drawing.

The upper end of the burette is provided with a Friedrich's patent two-way stop-cock, by means of which communication with the laboratory flask, or a laboratory vessel, to which it is connected by the branch tubes shown in the drawing, can be opened or closed at will.

The upper branch tube leading to the condenser and flask is 3 mm. bore; the lower branch is a capillary tube.

The two branch tubes are held against a wooden block, shown in the drawing, in cork-lined grooves, by a brass plate, also cork-lined, and screwed to the block. The grooves are made sufficient in width to allow of considerable play in a vertical direction.

This last precaution is necessary to allow for alteration in length of the burette induced by changes of temperature. When the tubes are properly fitted in these grooves, there is no danger whatever of their being broken, even if the apparatus is subjected to careless handling.

The contracted portion of the upper part of the burette is about 225 mm. long, and has a capacity of 15 c.cs., the wider portion being about 410 mm. long, with a capacity of somewhat more than 250 c.cs. Both portions are graduated, the former at intervals of one-tenth c.c., and the latter at intervals of 25 c.cs.

The pressure-tube has a working length of 1000 mm. above the level of the lowest division, viz. the 250 c.cs. line of the burette.

The height of the mercury in the pressure-tube is read by means of a millimetre scale etched on the unsilvered surface of a narrow slip of looking-glass, which is fixed to the back of the apparatus, close to the pressure-tube, at such an angle as to reflect the image of the tube through the portion of the glass bearing the scale. To read the height of the mercury in the tube, the eye is held a little to the right of the scale, and moved about until the scale-lines in the immediate vicinity of the reflected image of the mercury meniscus coincide with their own images reflected from the silvered surface of the glass. When the eye is in this position, the height of the mercury in the tube can be accurately read to 0.5 mm.

The laboratory vessel differs in principle and shape from that used in Frankland's and M'Cleod's apparatus. Its shape is shown in the drawing; the lower end, which is cylindrical in shape, is 25 mm. diameter, and 55 mm. long, and is furnished with a side tube for connecting the vessel with a separate

reservoir. The middle portion of the vessel is 160 mm. long, and the upper end has an inverted conical shape, which is 55 mm. long, the diameter increasing from 3 or 4 mm. at the lower, or narrow part, to 20 mm. at the mouth.

Two platinum wires are sealed into the vessel in the position shown in the drawing.

The special shape given to the upper portion of the laboratory vessel enables it to be easily connected, or disconnected with the burette. When the vessel is placed in position, as represented in the drawing, the capillary branch tube, the end of which is fitted with an indiarubber collar, tightly closes the narrower part of this portion of the vessel, while the lower shoulder of the vessel rests upon a shelf (shown in the drawing) which has somewhat the shape of a horseshoe. If the space above the rubber collar at the end of the branch capillary tube be filled with mercury or water, a perfectly air-tight joint is obtained. The joint may, in fact, be made so staunch, that a vacuum can be maintained in the vessel, or, on the other hand, explosions may be made therein without fear of loss.

When it is desired to disconnect the laboratory vessel, its lower portion is drawn forward sufficiently to clear the shelf, and it is then lowered to detach it from the branch tube from the burette.

By reversing these movements, the laboratory vessel may be again placed in its position. The shape of the indiarubber collar is of importance; its lower end must be shaped so as to bear well on the sides of the contracted portion of the laboratory vessel. The collar is easily given the necessary shape by means of a red-hot iron wire. The lower end of the laboratory vessel is closed by a well-fitting cork, through the centre of which passes a straight glass tube about 10 mm. long and 3 mm. bore; to the outer end of this a piece of stout indiarubber tubing, about 15 c.ms. long and 1 mm. bore, is attached.

When the cork is fixed into its place, the other end of this glass tube projects into the laboratory vessel for about 2 cts. A small Bunsen screw-clamp is provided, with which to open or close the rubber tube when necessary.

The glass tube supplies the means of introducing gaseous or liquid reagents into the laboratory vessel, and I therefore purpose to call it the reagent tube.

The side tube from the lower portion of the vessel is, as I have already stated, connected by means of a rubber tubing, with a separate reservoir, which is supported in a box,\* and raised or lowered along guides fitted at the back of the apparatus, by means similar to those already described as provided for the reservoir to the burette.

The shelf which supports the laboratory vessel is, in reality, a small bracket, the vertical limb of which is provided with a tongue at the back, sliding in a

\* The position of this box is not quite correctly shown in the drawing. Its true position will, however, be understood from the description in the letter-press.

groove cut in the wooden back of the apparatus, so that, thus guided, it can be moved up and down in a vertical direction, and clamped at any point by a thumb-screw, so as to adjust the amount of pressure which the upper end of the laboratory vessel will exercise on the rubber collar.

This adjustment provides for all alteration, either in the length of the laboratory vessel, owing to changes of temperature, or in the size of the rubber cork, owing to wear or replacement, and ensures an air-tight joint with the capillary tube from the burette at all times.

The whole apparatus is supported on a strongly-made table, 91 ctms. high.

The method of working the apparatus is as follows:—The pressure-tube, burette and laboratory vessel being filled with mercury, and all stopcocks closed, the laboratory vessel is placed in its position in the manner just described. The laboratory flask, into which 50 c.cs. of pure distilled water have been placed, with or without the addition of 1 or 2 c.cs. of pure sulphuric acid, as the experiment may require, has been placed, is fitted to the end of the condenser. The water in the flask is then boiled, the air and steam escaping through the side tube in the neck of the flask. The end of this tube is fitted with a short piece of indiarubber tubing. After continuing the boiling for about ten or fifteen minutes, the burner is removed from under the flask, and at the same time the short rubber tube, attached to the side tube from the neck, is closed with a piece of glass rod.

By this operation the flask is largely freed from air; the air still remaining in it, and in the condensing tube is next drawn off by working the apparatus as an air-pump. This is done by lowering the burette reservoir to its lowest limit, the mercury flowing out of the burette, leaving it in vacuo. If now the stopcock of the burette be turned to open communication between it and the laboratory flask, aqueous vapour and portions of the residuum of air left in the flask will pass into the burette. The stopcock is then turned to close communication with the laboratory flask, and the reservoir raised to refill the burette with mercury. The air and water drawn into the burette by this operation are then passed into the laboratory vessel by opening communication therewith. By this time the neck of the flask and the side tube therefrom will be sufficiently cooled to allow of water being safely poured into the space left in the neck above the rubber cork, by which the condensing tube is fitted into the flask, to protect it from the air, and to fit a water-jacket over the piece of rubber tubing closing the side tube.

The operation of drawing aqueous vapour and gases from the laboratory flask into the burette, and driving them thence into the laboratory vessel is repeated until the mercury, or rather the condensed water on the top of the mercury, strikes the closed stopcock of the burette with a sharp metallic click when the burette becomes full of mercury. In this way the burette provides an extremely

sensitive means of gauging the degree of exhaustion which can be obtained in the laboratory flask. The flask is usually exhausted by the time the burette has been filled with mercury, and emptied four or five times. The flask being exhausted, preparations are immediately made to transfer a known volume of the water to be examined, into the laboratory flask.

A few minutes' delay is first allowed to allow the surplus water left on the sides of the burette to collect at the top.

This is then transferred to the laboratory vessel, which is next detached from the capillary branch tube, care, however, been taken before doing so, to leave the branch tube full of mercury.

The rubber collar is detached from the end of this tube, which is then connected by means of a piece of indiarubber tube with a glass tube of the same thickness and bore as itself (27 cms. long), which has been previously completely filled with the water to be examined. The lower end of the latter tube is immersed in the water for examination, the burette reservoir lowered a little, and the stopcock opened, the water then passes into the burette.

By gradually lowering the reservoir, 250 c.cs., or a less volume if required, of the water may be drawn into the burette.

When this has been effected, the stopcock is closed, and opened to the laboratory flask. The water then passes into it from the burette, care being necessary to prevent mercury getting into the flask during the operation. The glass tube is now detached from the capillary branch, the rubber collar reattached, and the laboratory vessel refixed in position. It is now necessary to clear the laboratory vessel of small bubbles of air, and of any decided quantities of water that may remain on its sides or in the reagent tube from the process of washing after the previous analysis. This is rapidly done by raising the reservoir decidedly above the level of the side tube of the vessel, and unscrewing the clip which closes the rubber tube attached to the outer end of the reagent tube, so as to allow mercury to pass into the pipette attached to the other end of the rubber tube and supported by a clip, fixed to the stand, in the position shown in the drawing. The reservoir is then dropped considerably, and the screw-clip being cautiously opened, the greater portion of the mercury in the pipette is drawn back into the laboratory vessel, carrying with it any air-bubble or water which may have lodged in the reagent tube. The clip being closed, the reservoir is raised sufficiently to cause the mercury to overflow the laboratory vessel when it is slightly withdrawn from the rubber collar on the capillary branch tube, thus driving out the air and water from the top of the vessel. The laboratory vessel is refixed in position, and the reservoir is then lowered so as to empty the vessel almost completely, and being rapidly raised, note is made as to whether the sharp click is heard when the vessel refills completely. If not, it is

again partly detached from the collar, and some mercury driven out, and the vessel again replaced in position. These operations of causing the mercury to overflow the top, lowering the reservoir so as to nearly empty, and again rapidly refilling the vessel, are continued till the sharp click, indicative of complete exhaustion, is obtained. Generally, this is obtained after two or three trials, the operation being extremely easy.

During the time occupied in these manipulations, the water in the laboratory flask is kept violently boiling to disengage the dissolved gases.

These are drawn into the burette from the flask, and stored in the laboratory vessel in a similar manner to that described for exhausting the flask in the first instance, with the exception that the condensed aqueous vapour, drawn into the burette with the dissolved gases, is not allowed to pass into the laboratory vessel, but is returned to the flask. When the dissolved gases have been completely extracted, a few minutes delay are allowed for the small quantities of water, adherent to the sides of the burette, to rise to the top, when it is returned to the flask. The measurement and analysis of the gases stored in the laboratory vessel is then proceeded with.

The method of adjusting the level of the mercury in the burette, after the gases have been passed into it, will require some explanation. The simple plan of closing the stopcock, and then raising and lowering the reservoir so as to bring the mercury to the level of the division line selected cannot always be followed, since, after transferring the gas, a small bubble of it sometimes remains in the laboratory vessel under the rubber collar, and cannot be removed therefrom. When, therefore, the level of the mercury in the burette is being adjusted, the stopcock must be left open, and the adjustment be made by working the two reservoirs conjointly. To transfer the gases into the burette in the first instance, its reservoir is lowered, and that of the laboratory vessel is raised, if necessary, until nearly all the gas is passed over, a little, however, remaining in the laboratory vessel. It must be observed at this point whether the gas will require to be compressed or expanded in order that the mercury in the burette shall stand, after final adjustment, at the level of the division line selected for measurement, and in order that, at the same time, the laboratory vessel shall be completely filled with mercury, with the exception, possibly, of the small bubble of gas above referred to; with careful manipulation, however, no bubble of gas need remain. With a little practice, the adjustment may be effected easily and quickly. An indication that all the gas possible has been transferred to the burette at the final adjustment, is obtained when the mercury, or more generally water, since a small quantity always collects in the laboratory vessel during the operation of extracting the gases from the laboratory flask, and storing them, as above described, rises a little in the capillary branch tube.

When the necessary adjustments have been made, the height of the mercury in the pressure tube, which, I should here note, is kept moist, is read off, the line of measurement on the burette and the temperature of the water in the jacket, are also noted. The next step is to absorb the carbon dioxide; the small quantity of solution of potassium hydrate required for this purpose is introduced into the laboratory vessel thus:—the stopcock of the burette is closed, the reservoir of the laboratory vessel is fixed well above the level of the reagent tube, and a pipette containing the solution of potassium hydrate is connected to the free end of the rubber tube attached to the reagent tube, and then left supported, as indicated in the drawing.

As the reservoir is now above the level of the reagent tube, on unscrewing the clamp the mercury will flow into the pipette, and expel any small bubble of air that may have been left in the open end of the rubber tube after attaching the pipette to it. The air having been completely expelled, the clamp is screwed up again, and the reservoir dropped to a level a little below that of the reagent tube.

On carefully opening the clamp the mercury in the pipette will slowly flow back into the laboratory vessel, and after it the required amount of potash solution, care being used so as not to empty the pipette entirely. As soon as this is accomplished, the clamp is closed, and the reservoir raised to about its former level. The surplus quantity of solution remaining in the reagent tube may now be driven back into the pipette, and after it a little mercury, by carefully opening the clamp, which is closed again immediately this has been done. To effect the absorption of the carbon dioxide by the potash, the gas is passed into the laboratory vessel, and then backwards and forwards into the burette three or four times, care being taken not to allow any of the potash into the burette. In about five minutes the carbon dioxide will be completely absorbed, and the remaining gas again measured just as before, and the height of the mercury in the pressure tube noted, the difference of reading before and after absorption giving the pressure exerted by the carbon dioxide at the volume at which the gases have been measured.

If the volume of this gas has been large, it will reduce the errors of reading in the further process of analysis, if the remaining measurements be made at a volume less than that which was necessary before absorbing the carbon dioxide. The operation of absorbing the oxygen by means of pyrogallie acid is carried on similarly to that for absorbing the carbon dioxide. The remaining gas will consist, at least in most cases, of pure nitrogen. Its pressure at the volume at which the measurements for the determination of the oxygen were made, is easily determined by deducting from the last noted pressure the height of mercury in the pressure tube corresponding to the height of mercury in the burette at the line

at which the measurement for the determination of the oxygen was made. This height may be quickly determined for each experiment by noting the height of mercury in the pressure tube, when the mercury in the burette is adjusted at the said line of measurement in vacuo.

The residual gas, after the absorption of the carbon dioxide and oxygen, may, in some cases, contain hydrogen, and possibly marsh gas.

When this is the case the following procedure is adopted:—

After carbon dioxide and oxygen have been absorbed and determined, the remaining gases are driven back into the laboratory flask, and the laboratory vessel and burette are very carefully cleaned.

To do this the reagents in the laboratory vessel are driven gradually above the rubber collar on the end of the capillary branch tube by lowering the vessel a little from the collar, and carefully raising its reservoir. As the reagents rise above the collar they are absorbed by means of blotting paper. When the vessel has been cleansed by this means as far as possible, it is replaced in position, and about 50 c.cs. of dilute sulphuric acid (1 : 3) are introduced into it through the reagent tube. A little of the acid is allowed to rise above the rubber collar to neutralize the potash adherent to it, and the remainder is drawn into the burette.

The laboratory vessel is then completely detached from the capillary branch tube, and the acid, after having been drawn down nearly to the bottom of the burette, is discharged from it into a beaker.

The laboratory vessel is next placed in position and filled with tap-water through the reagent tube, and a similar series of operations again carried out as above described, with the view of washing both vessel and burette free from acid; the washing is repeated two or three times with distilled water.

When the operation of washing has been completed, the liquid in the laboratory flask is boiled, and the gases drawn from it into the burette and laboratory vessel, with the precaution previously described for their complete expulsion. After their measurement, some pure oxygen is introduced into the laboratory vessel through the reagent tube in a manner exactly similar in principle to that above described for the introduction of liquid reagents. The mixed gases and oxygen are then measured, and exploded under reduced pressure, and the further analysis proceeded with in the ordinary way.

Since the water surrounding the burette becomes unequally heated during the process of extracting the gases from the laboratory flask, it is necessary to replace it before measuring and analysing the gases. This is readily done by syphoning off the water immediately after the process of exhausting the flask has been completed, and replacing it with some that has been exposed for some time to the temperature of the laboratory.

I ought to note, before concluding this description, that it has been ascertained by experiments, which are detailed in my Paper on the earlier form of the apparatus already referred to, that the bubble of gas, which is sometimes retained in the laboratory vessel during measurement, does not introduce appreciable errors therein.

#### **Extraction of the Gases in Solution.**

Although it is impossible to completely exhaust a water of the gases it holds in solution in vacuo in the manner I have described, it is nevertheless possible to carry the exhaustion so far that the quantities of the respective gases left behind in the water may be disregarded, as experience has shown that they do not appreciably affect the results.

Both oxygen and nitrogen are readily extracted from the water, and transferred to the laboratory vessel for measurement by three or four exhaustions of the flask during the boiling of the water in it, but the carbon dioxide is not so easily disengaged, and between a quarter and half an hour's ebullition in vacuo is usually necessary to effect its removal, the length of time depending on the quantity of this gas in solution, and also, apparently, upon the dissolved mineral matters also, a hard water requiring more boiling than a soft one.

Owing to the slowness with which bicarbonates decompose when boiled, I have found it practically impossible to determine, separately, the "combined" and "uncombined" carbon dioxide in a water. But the total carbon dioxide is readily estimated by boiling the water with a suitable acid, and by the term carbon dioxide I shall hereafter always include the combined carbon dioxide with that which may be held in solution uncombined.

The acid I have used for this purpose has invariably been sulphuric acid. When its presence has been necessary, I have always added it to the water placed in the flask in the first instance, preparatory to exhausting the air from the flask, as already described.

The presence of the acid does not interfere with the determination of the oxygen and nitrogen, unless, of course, nitrites are present in the water. When this is the case, the dissolved oxygen and nitrogen are determined in the absence of acid, and the carbon dioxide afterwards estimated by a separate experiment in the presence of acid.

I have generally employed 250 c.cs. to 500 c.cs. of a water for the analysis of the dissolved gases; such volumes of water giving suitable volumes of gases for the apparatus. The operation of extracting and analysing the dissolved gases in a water may generally be completed within two hours.

### Methods employed for the determination of Inorganic Nitrogen.

The nitrogen as ammonia has been determined in the ordinary way by nesslerizing after distillation, with the exception of a few cases, when it was necessary to directly nesslerize without previous distillation, owing to the fact that the substances experimented with were decomposed on boiling.

The method employed for estimating the nitric acid was that which has been worked out by Williams,\* and which depends upon the action of a "zinc-copper couple" in reducing nitrates and nitrites to ammonia. My general experience with this method is, that it gives reliable results.

For the estimation of nitrous acid, I have employed Griess' metaphenylenediamine method, as detailed in Sutton's "Volumetric Analysis," p. 367, 5th edition.

Wherever possible, that is when the total quantity of inorganic nitrogen has not been large, I have preferred to subject the water to the action of the "zinc-copper couple" before distilling off the free ammonia present.

The nitrogen as free ammonia then obtained, after the action of the couple, represents the total inorganic nitrogen. This amount, less that as free ammonia originally present, and nitrous acid, which are separately determined, gives the nitrogen present as nitric acid.

When, however, the free ammonia or nitrous acid is present in large quantity, I have separated them in the ordinary way, the free ammonia by distillation, and the nitrous acid by distillation in the presence of an excess of ammonium chloride, before examining the water for nitric acid. I have occasionally employed Crum's method with Lunge's nitrometer to check the results obtained with the zinc-copper couple method, and have usually obtained concordant results therewith.

### Errors.

The methods of experiment which I have described are liable to three distinct sources of error. They are:—

1. The possible changes in volume which the dissolved gases may suffer during the manipulation necessary for bottling the water, and transferring it to the gas analysis apparatus.

2. The operations in the gas analysis apparatus, viz. the extraction and analysis of the dissolved gases.

\* C. S. J., 1881, 100.

3. The changes of temperature which the solutions undergo during the time of keeping them in bottles, as described, out of contact with air.

It would be difficult to give a precise value for each of these three sources of error, but their total effect upon the final results obtained, which are, it must be remembered, the differences between the determinations for each dissolved gas before and after keeping the liquid under the prescribed conditions, will be found approximately indicated in the majority of the experiments which I shall describe in this Paper, by the atmospheric nitrogen determinations.

Since most of my experiments have been carried on under more or less aërobic conditions, the atmospheric nitrogen has not, except apparently in a few cases, suffered changes in common with the other bodies with which it has been associated. The difference between the volume of this gas before and after fermentation, therefore, affords a very valuable index of the extent to which the above possible sources of error affect the analytical results.

The total error may also be found practically by blank experiments with the water employed for making up the solutions.

I have usually found the difference between the determination of the volumes of nitrogen before and after keeping to be under 0.2 c.c. per litre of water. In some cases it has risen nearly to 0.3 c.c., but this is exceptional.

Blank experiments with tap-water, the particulars of which will be given later on with the details of my other experiments, show that the oxygen determinations before and after keeping do not usually differ by more than 0.1 c.c., and rarely differ by as much as 0.15 c.c. per litre of water.

The error attending the determination of carbon dioxide varies somewhat with the quantity, and probably also with the composition of the mineral matter in solution in the water. When the quantity is not greater than 40 or 50 c.cs. per litre, the error is about the same as that affecting the nitrogen determination, but, as the quantity increases, the error is liable to slowly increase also, and may reach to as much as 1.0 c.c. per litre for quantities amounting to 200 c.cs. per litre. In the case of a hard spring water in which the carbon dioxide reached to nearly 300 c.cs. per litre, the determinations of this gas before and after keeping showed differences of as much as 2 c.cs., although the atmospheric nitrogen and oxygen determinations were similar, and indicated that no fermentation had gone on therein during the time of keeping it. In consequence of this, I have avoided, when possible, the presence of any large quantity of carbon dioxide, and have employed sodium carbonate only, when it was necessary to add a carbonate to my test solutions.

The errors of the gas analysis apparatus are very small, and need not be discussed, since I have dealt with them in the Paper already referred to, describing the earlier form of the instrument.

It will be seen from the foregoing remarks, that, although the method is open to several sources of error, it is possible to keep the total error within such narrow limits that valuable results may be obtained by it. But in order to effect this, it is necessary to observe certain precautions in carrying out some of the steps in the method, and to these precautions I will now briefly refer.

### **The Preparation and Analysis of the Solutions and Dilutions.**

In the first place the tap-water employed was that supplied to Dublin from the Vartry Waterworks. It is a good upland surface water, and has proved a valuable one for the purposes of my experiments, since it contains extremely small quantities of dissolved matters, the total solids being usually not more than four parts per 100,000 of water. It, however, invariably contains small quantities of peaty colouring matter, and for this reason I have sometimes found it necessary to use pure distilled water instead. The water was drawn from a large cistern holding nearly 400 gallons.

When making up a long series of dilutions for observation, it has, of course, been impossible to determine the gases in each member of the series just before bottling, since the time required for so many analyses would be so considerable that it would be impossible to prevent serious changes of temperature, and also, in all probability, fermentative changes, especially if sewage-water happened to be the subject of experiment, and the final results would therefore not be comparable. When dealing, therefore, with a series of dilutions at the commencement of an experiment, I have determined the dissolved gases and inorganic nitrogenous bodies in the lowest dilutions, and in the tap-water employed for making the dilutions, only, and calculated, from the data obtained, the quantities of dissolved gases and inorganic nitrogenous substances for all the other dilutions made up. I need scarcely remark that at the conclusion of an experiment each member of the series of dilutions has been in every case directly analysed.

I have adopted a similar method of preparation for all the dilutions I have experimented with. The basis of each series of dilutions has been either undiluted sewage-water, or a strong solution of other substances of known composition and strength. Five litres, at least, of the lowest dilution have been made, and aerated by violent agitation with air in a large glass vessel fitted with a glass tap. After the aëration the solution has been allowed to rest for about fifteen minutes, to allow air-bubbles to rise to the surface and escape.

Two or more bottles have then been carefully filled, and allowed to stand unstoppered for a few minutes, until again all air-bubbles have escaped. All the

bottles, with the exception of one, were then carefully stoppered, and placed neck downwards in distilled water. The one left unstoppered was at the same time transferred to the gas analysis apparatus, and the volume of the liquid required for the analysis then drawn from it into the burette of the apparatus, and thence passed into the laboratory flask, and boiled in vacuo.

Immediately this had been done, the preparation of the remaining dilutions required is proceeded with in an exactly similar manner, except that portions of them were not reserved for analysis.

When all the dilutions have been made, five litres of tap-water were placed in the same glass vessel, and agitated with air just as in the case of the dilutions. The water after aëration is drawn off into bottles and preserved in the ordinary way, a portion, as in the case of the lowest solution, being transferred to the gas analysis apparatus. With the aid of an assistant, the analysis of the lowest dilution and the preparation of all the required dilutions may be completed within two hours, when the aëration, bottling, and analysis of the tap-water may be proceeded with without delay.

The chief point of importance to be attended to in the preparation of these dilutions is that of temperature; it should be the same for each dilution. This is not difficult to accomplish when the tap-water is drawn from so large a cistern as that which has furnished my supply. I have also taken the precaution of tying up the ball-cock of the cistern when making up the dilutions.

The complete aëration of the dilutions is also of importance; but, with a good tap-water such as I have employed, this condition can be attained without difficulty.

In all my experiments I have endeavoured to keep the variation of temperature from that obtaining at their commencement within as narrow limits as possible, and as a result of this I have found it unnecessary to make any correction for expansion or contraction of the liquid arising from change of temperature, the errors arising therefrom being very small in comparison with those from other sources; thus the maximum difference between the initial and final temperature of any of the experiments I shall quote in this Paper has been within  $12^{\circ}$  C., viz. from  $8^{\circ}$  C. to  $19^{\circ}$  C. A litre of water, on rising from  $8^{\circ}$  C. to  $19^{\circ}$  C., would increase (according to the data given in Muir and Morley's edition of "Watt's Dictionary," vol. iv., p. 861) in volume by 1.409 c.cs. Such an alteration in volume, it will be seen from the details of my experiments, gave rise to so small an error in comparison with others which affected them that it was thought unnecessary to make any correction for it.

The errors arising from the tendency to disengagement of the dissolved gases on variation of temperature would of course be very large, and in fact would render the results valueless had not the precaution already described been taken

to prevent the escape of the disengaged gases from the bottle in which the solution was kept.

The conditions which give rise to the maximum disengagement of gases from liquids kept in bottles, in the manner I have already explained when describing the method of experiment adopted, and apparatus employed for this investigation, are, first, a considerable rise of temperature above the initial point, during which the liquid will expand, and small quantities of it be forced out of the bottle between the neck and the stopper, followed by a considerable fall, when the liquid will contract, and, if the stopper be well ground, a small space will be formed in the bottle containing gases previously dissolved, and will be more or less steadily maintained, since the bottle is immersed in water, neck downwards, so long as the temperature remains below the maximum point to which it was formerly raised. The relation between the quantity of each gas disengaged in this way to that remaining in solution will practically vary with the temperature, according to Henry's law.

As a practical illustration of the influence of variation of temperature upon solutions kept under the conditions described, I may here give an extreme case, viz. an experiment with tap-water kept for a period of fourteen months.

This experiment was started on the 2nd February, 1893, when the tap-water before bottling was violently shaken up with air in a large vessel. After this operation the water was allowed to stand until quite free from air-bubbles. Its temperature was then found to be  $10^{\circ}\text{C}$ . A bottle was carefully filled with a portion of the aerated water, another portion being immediately afterwards transferred to the laboratory flask of the gas analysis apparatus. On April 3rd of the following year the contents of the bottle were examined. A bubble of gas, about 6 c.cs. in volume, was found to have been formed. The gases in the bubble were collected over fully aerated distilled water, and immediately afterwards transferred to the laboratory vessel of the gas analysis apparatus, measured, and analysed; the water in the bottle was not examined until next day, in order to allow time for the distilled water, which had replaced the disengaged gases, to diffuse equally through it. During this time, it need scarcely be said, the bottle was kept immersed in water.

The temperature at the conclusion of the experiment was  $13^{\circ}\cdot 8\text{C}$ .

The results of the analysis of the disengaged gases were as follows:—

Total volume at $0^{\circ}\text{C}$ . and 760 mm. Bar,	. . . . .	5·8414 c.cs.
Volume of oxygen	„ „ . . . . .	1·0058
Volume of nitrogen,	. . . . .	4·8356
Volume of carbon dioxide,	. . . . .	0

The capacity of the bottle was 2530 c.cs. Dividing the volumes of oxygen and nitrogen by 2·53, we get the volumes of these gases disengaged, per litre of water, at the time of the conclusion of the experiment. These volumes are :—

Oxygen,	. . . . .	0·40 c.cs.
Nitrogen,	. . . . .	1·91

The results of the analysis of the gases\* dissolved in the water at the commencement and conclusion of the experiment are given in full in the following Table :—

—	CO <sub>2</sub> .	O <sub>2</sub> .	N <sub>2</sub> .	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>
At commencement, . . . . .	4·04	7·8	15·60	0	0·0001
At conclusion, . . . . .	4·94	6·23	13·60	0	0·0008
Correction for disengaged gases, . .	0	0·40	1·91	—	—
Corrected vols., . . . . .	4·94	6·63	15·50	—	—
Differences, . . . . .	+ 0·90	— 1·17	— 0·10	—	+ 0·0007

No correction was made for the distilled water introduced into the bottle when collecting the disengaged gases.

The changes in volume of the carbon dioxide and oxygen shown in the above Table were no doubt due to the fermentation of small quantities of peaty colouring-matter which the tap-water contained, and not to experimental errors. This explanation is supported by the increased quantity of nitrate found in the water after keeping.

The gaseous nitrogen, however, remained unchanged in volume during the period of keeping, and the difference between the volume of this gas found before and after keeping indicates the probable value of the total error from the two distinct sources mentioned above.

Before leaving the consideration of errors due to variation of temperature of the solutions during the time of keeping them, I ought perhaps to point out that a disengagement of dissolved gases on rise of temperature is more or less completely prevented under the ordinary conditions of my experiments, since a considerable pressure was always kept up in the bottles when the temperature was rising, by keeping them resting with their full weight upon their stoppers.

This I have generally found sufficient to prevent the stoppers from becoming too freely loosened by the expanding force of the water under the influence of rise of temperature. I should add that care has been taken to guard the solutions against any serious daily variations of temperature, and the precaution of re-tightening the stoppers from time to time has also been taken.

\* Volumes of the gases are expressed in c.cs., at N.T.P., per litre of water.

## PART I.

**Experiments with easily Fermentable Matters.**

As I have already explained when describing the method of experimenting adopted, the experiments which I have now to record have for the most part been carried out with sets or series of dilutions, varying in strength, of comparatively strong solutions of polluted waters, such as sewage-water, or of other fermentable substances, including those which ferment with ease, and those which ferment with difficulty.

The details and results of the experiments are given in full in Tables, a separate Table to each set or series of experiments. Each Table, therefore, furnishes a fairly complete view of the nature and amount of the chief substances produced by the action of the mixed organisms natural to the solution or dilution during a fermentaton, carried on under conditions varying within narrow and well-defined limits, as well as the quantity of oxygen consumed in the process.

The information given in these Tables will, therefore, be found sufficiently full to render them self-explanatory.

But it will be necessary to discuss the results in some of the Tables at some length in order to indicate the typical results, which the method of experimenting employed can afford, and the general conclusions which can be drawn therefrom. The remaining Tables will be found to furnish additional experimental results, all tending to confirm those specially referred to.

It will be convenient to discuss, in the first place, the experiments with easily fermentable organic matters; and this I now propose to do, not necessarily in chronological order, but as they best illustrate the points which have to be considered.

My first definite series of experiments was commenced on November 5th, 1891, and they were made with a sample of raw sewage collected from a main sewer at Monkstown, a residential suburb of Dublin. The sample of sewage was filtered through ordinary filter-paper to separate the matters in suspension as much as possible, and aërated, and the following dilutions were made from it with tap-water:—one volume of filtered sewage to 9, 19, 29, 39, 49, 59, 69, 79, 89, and 99 volumes of tap-water.

In the following, and all succeeding Tables giving the details and results of experiments, the dissolved gases are expressed in c.cs., at 0° C., and 760 mm. bar., and the inorganic nitrogen in fractions of a gramme, per 100 c.cs., of solution.

Under the columns headed I. and II. are given the results of analysis, before and after fermentation, respectively.

[TABLE I.  
4 L

## SERIES I.—COMMENCED 25TH NOVEMBER, 1891.

TABLE I.—*The Volume of Gases, and the Weights of Ammoniacal and Nitric Nitrogen, in the Mixtures of Sewage and Tap-Water, employed in Series I. of Experiments, before and after Fermentation.*

[The gases are expressed in c.cs., measured at 0°C., and 760 mm. bar.; the other constituents, as parts by weight, per 1000 c.cs. of liquid.]

Date of conclusion of Experiment.	Mixture.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>	
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
1892. January 21	1 in 100 Differences, . .	4.32 + 2.38	6.70	8.03 - 5.49]	2.54	15.96 ..	15.60	0.0062 - 0.00062	0.00	0.00010 + 0.0009	0.0010
February 3	1 in 90 Differences, . .	4.43 + 2.72	7.15	8.02 - 6.34	1.68	15.96 ..	15.61	0.0067 - 0.00067	0.00	0.0001 + 0.0011	0.0012
February 4	1 in 80 Differences, . .	4.51 + 3.13	7.64	8.02 - 7.25	0.77	15.90 ..	15.60	0.0077 - 0.00077	trace.	0.0001 + 0.0011	0.0012
February 4	1 in 70 Differences, . .	4.66 + 3.28	7.94	8.00 - 7.38	0.62	15.96 ..	15.60	0.0086 - 0.00074	0.00012	0.0001 + 0.0011	0.0012
February 5	1 in 60 Differences, . .	4.81 + 4.37	9.18	8.00 - 7.52	0.48	15.97 ..	15.68	0.0010 - 0.0002	0.0008	0.0001 + 0.0007	0.0008
February 5	1 in 50 Differences, . .	5.09 + 5.14	10.23	7.98 - 7.98	0.00	15.97 ..	15.55	0.0012 - 0.00	0.0012	0.0001 + 0.0005	0.0006
February 5	1 in 40 Differences, . .	5.46 + 6.09	11.55	7.96 - 7.96	0.00	15.99 ..	15.51	0.0015 + 0.0004	0.0019	0.0001 + 0.0003	0.0004
February 6	1 in 30 Differences, . .	6.08 + 7.03	13.11	7.92 - 7.92	0.00	15.98 ..	15.79	0.002 + 0.0012	0.0032	0.0001 - 0.0001	0.00
February 11	1 in 20 Differences, . .	7.31 + 11.25	18.56*	7.85 - 7.85	0.00	15.99 ..	15.80	0.003 + 0.002	0.005	0.0001 - 0.0001	0.00
February 11	1 in 10 Differences, . .	11.03 + 15.37	26.40*	7.63 - 7.63	0.00	16.07 ..	20.09†	0.006 + 0.0008	0.0068	0.00 0.00	0.00
February 15	Tap-water, . .	3.58   3.45		8.07   8.00		15.95   15.82		0.00   0.00		0.0001   0.0001	

REMARKS.—Nitrous acid was not detected in any of the mixtures after fermentation. Mixtures 1/100 to 1/50 were quite inodorous after fermentation. 1/40 emitted an odour like that of rain-water. 1/30, 1/20, and 1/10 were very offensive.

\* Each of these volumes include small quantities of SH<sub>2</sub>.

† This volume includes CH<sub>4</sub> and H. The volume of these gases was not determined owing to an accident during analysis.

The foregoing Table illustrates very clearly the results which are obtained by the fermentation of dilutions of the same sewage-water under conditions gradually varying from those in which the atmospheric oxygen is in excess, relatively to the fermentable matters, to those in which the fermentable matters are in excess.

Solutions 1/100 to 1/80 afford an illustration of the influence of an excess of oxygen. In each of these solutions the fermentation has extended to the complete oxidation of the ammonia in the admixed sewage. In solutions 1/70 and 1/60 the conditions were evidently evenly balanced, for both a little free oxygen and a little ammonia were left in each. In solutions 1/50 and 1/40 the influence of gradually increasing quantities of fermentable matters in proportion to atmospheric oxygen is indicated by increasingly small quantities of nitrogen becoming oxidised, and by increasingly large quantities of ammonia left unoxidised. In solutions 1/30 and 1/20 we see that no oxidation whatever of nitrogen took place, and we notice for the first time that the volume of carbon dioxide begins to show a slight decrease relatively to the volumes of the gas formed in the more dilute solutions after fermentation. This is still more noticeable in the strongest solution 1/10. In this connection it is of interest to note that, simultaneously with the relative decrease in volume of carbon dioxide formed, bodies having offensive odours begin to make their appearance.

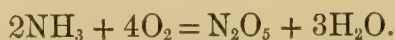
If we examine the contents of the Table a little more closely, we shall find that a number of important conclusions may be drawn as to the quantitative relationships existing between the amounts of atmospheric oxygen, and of fermentable matters originally present in the solutions on the one hand, and the products of fermentative changes on the other. These relationships become more apparent when each set of differences between the analytical results given in the Table for each solution are multiplied so as to make them comparable with one another. When so multiplied, the numbers may also be taken to represent the results which would have been obtained by experimenting with undiluted sewage, had that been possible, under the respective conditions represented by each dilution. In the following Table are given the products obtained by multiplying the differences in Table I. as described :—

[TABLE II.

TABLE II.

Solution.	Multiplier.	1. CO <sub>2</sub>	2. N as NH <sub>3</sub>	3. N as N <sub>2</sub> O <sub>5</sub>	4. O in c.cs. equiv. to N <sub>2</sub> O <sub>5</sub>	5. Sum of 1 and 4.	6. Vol. of O absorbed.
1/100	100	+ 238	- 0.062	+ 0.09	287	525	549
1/90	90	+ 245	- 0.060	+ 0.099	316	561	571
1/80	80	+ 254	- 0.062	+ 0.088	281	535	580
1/70	70	+ 230	- 0.052	+ 0.077	245	475	517
1/60	60	+ 262	- 0.012	+ 0.042	134	396	451
1/50	50	+ 257	0.0	+ 0.025	80	337	399
1/40	40	+ 244	+ 0.016	+ 0.012	38	282	318
1/30	30	+ 211	+ 0.036	0.0	0	211	238
1/20	20	+ 225	+ 0.04	0.0	0	225	157
1/10	10	+ 154	+ 0.008	0.0	0	154	76

The volume of oxygen given in column 4 as equivalent to the weights of N<sub>2</sub>O<sub>5</sub> in the preceding column have been added for convenience of comparison; they have been calculated from the equation:—



This equation gives 3.19 c.cs., oxygen at N.T.P. as the volume required to oxidize 0.001 grammes nitrogen as NH<sub>3</sub> to N<sub>2</sub>O<sub>5</sub>.

Column 5 gives the sum of the volumes of carbon dioxide actually formed, and of oxygen theoretically equivalent to the nitric acid formed, and have also been added for comparison with the volumes of oxygen actually consumed.

The figures in the above Table, when allowance is made for errors, show that in the case of each of the solutions 1/100, 1/90, 1/80, in which the fermentation extended to the complete oxidation of ammonia, the quantities of carbon dioxide and nitric acid formed, and the volume of oxygen absorbed, were practically directly proportional to the quantities of fermentable matter originally present in them.

We also see that in all the other solutions down to 1/40, in which the sewage matters were gradually increased in relation to the dissolved oxygen, the volume of carbon dioxide formed was still directly proportional to the quantities of sewage matters originally present therein, and that the first effect of gradually increasing the proportion of sewage matters was the oxidation of relatively smaller quantities of ammonia; and as the proportions of sewage matters were still further increased, the ammonia began to be formed, instead of oxidized.

In the solution 1/40 the proportion of sewage-matters to dissolved oxygen was evidently pushed to its maximum. That is to say, the dissolved oxygen present was only just sufficient for the completion of the first stage of the fermentation of the organic matters, viz. the breaking down of the organic matters into carbon dioxide, water, and ammonia.

Hence, from the results of these experiments, if the fermentation of sewage matters really takes place in the two stages already referred to, we may tentatively conclude that when the dissolved oxygen is present in sufficient quantity for the completion of both stages, the quantities of carbon dioxide and nitric acid formed, and the volume of the dissolved oxygen absorbed, are directly proportional to the quantity of sewage-matters originally present.

If, however, the oxygen be not in sufficient quantity for the completion of both stages, but that of the first only, then the volume of carbon dioxide formed is still directly proportional to the quantities of sewage-matters originally present, and the oxidation of ammonia will or will not proceed according as there happens to be an excess or not of oxygen over and above that required for the first stage of fermentation.

In the solutions 1/30, 1/20, and 1/10 we have an insufficient quantity of dissolved oxygen for the completion of the first stage of fermentation. We then see a secondary, or an aërobic, fermentation sets in, in which the fermentation of the organic matter has been proportionally less and less complete as the quantity of sewage-matter increased. No simple relation between the carbon dioxide formed, and the quantity of sewage-matter originally present is apparent under this condition.

We may go further, and sum up the results given in the two Tables in a definite quantitative form, thus:—1000 volumes of the sample of sewage-water experimented with required 580 volumes of atmospheric oxygen, with a probable error of 15 volumes, for the complete fermentation of the fermentable matters, 280 volumes of which were required for the completion of the first stage, and 300 volumes for the second stage of fermentation. Or we may put it in another way, and state that when 1 volume of the sewage-water was mixed with 39 volumes of good river-water, fully aërated and fairly pure, at winter temperature, the oxygen dissolved in the river-water was sufficient for the first stage of fermentation; and, when mixed with 69 volumes, the supply of dissolved oxygen was sufficient for both stages of fermentation of the admixed sewage-matters. The atmospheric nitrogen determination for the solutions 1/100 to 1/40 inclusive, show greater differences than will be found usual. These may possibly not be due to experimental errors, but rather to “fixation” of atmospheric nitrogen during fermentation (see p. 587).

It should be noted that the tap-water used for diluting the sewage-water suffered but little, if any, change during the period of keeping.

Although the results afforded by this series of results were definite enough to warrant the conclusions I have formulated, they could not be considered as constituting a sufficient basis for extending these conclusions to polluted and natural waters generally.

Other waters, whether polluted with sewage-matters or vegetable matters such as peat, might contain fermentable substances of different composition, and organisms of different chemical functions; and such waters, when similarly examined, might give rise to results which might lead to different conclusions. It was therefore necessary to extend my observations to polluted and natural waters differing widely in character from one another.

I first, however, made some further experiments with other samples of sewage-water taken from the same locality as that from which the sample employed in my first series of experiments was taken. These confirmed the results I have already given, and need not be recorded here.

As examples of results obtained with sewage-water from quite a different locality, I will give those of two series of experiments with two samples, for which I was indebted to the kindness of Mr. J. C. Melliss, C.E., of London. Both samples were taken on June 21st, 1893, from the Richmond Main Drainage Works, near London, one being of raw sewage before treatment, and the other of sewage-water after clarification with lime and sulphate of alumina, and a very careful filtration through one of the gravel filter-beds with which the works are furnished. Each sample was an average of portions collected hourly from 6 A.M. to 6 P.M.

The raw sewage was filtered and aerated, and the following dilutions were made as before:—1 volume of raw sewage to 9, 19, 39, and 79 volumes of tap-water. The particulars of the experiments are given in the subjoined Table:—

## SERIES II.—COMMENCED 24TH JUNE, 1893.

TABLE III.—*Experiments with Sewage- and Tap-water.*

Date of conclusion of Experiment.	Solution.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>		REMARKS.
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	
1893 July 25	1 in 10 Differences, . .	23·35 + 6·09	29·44	6·42 - 6·42	0·00	13·41 ..	20·83* ..	0·0045 + 0·0002	0·0047	0·00009 - 0·00009	0·00	Solution very offensive after fermentation.
July 26	1 in 20 Differences, . .	14·21 + 5·57	19·78	6·44 - 6·26	0·18	13·41 ..	13·49 ..	0·00225 + 0·00025	0·0025	0·00009 - 0·00009	0·00	Solution free from odour after fermentation.
July 26	1 in 40 † Differences, . .	9·64 + 2·81	12·45	6·46 - 3·30	3·16	13·41 ..	13·49 ..	0·001125 + 0·000025	0·00115	0·0001 0·00	0·0001	Ditto.
Sept. 1	1 in 80 Differences, . .	7·36 + 1·81	9·17	6·46 - 4·34	2·12	13·41 ..	13·34 ..	0·00056 - 0·00056	0·00	0·0001 + 0·0007	0·0008	Ditto.

It may be remarked that nitrous acid was *not* detected in any of the solutions of this series of experiments.

\* This volume includes N, CH<sub>4</sub>, and H, disengaged during fermentation, but they were not separately determined.

† The remainder of this solution was, immediately after examination, re-aerated, analysed, and set aside to ferment till September 1st, when it was re-examined, with the following results :—

1893 Sept. 1	.. Differences, . .	11·31 + 0·68	11·99	5·78 - 4·34	1·44	12·96 ..	12·99 ..	0·00115 - 0·00115	0·00	0·0001 + 0·0016	0·0017	..
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Multiplying each set of differences as before, we get:—

TABLE IV.

Solution.	Multiplier.	1. CO <sub>2</sub>	2. N as NH <sub>3</sub>	3. N as N <sub>2</sub> O <sub>5</sub>	4. O in c.cs. = N <sub>2</sub> O <sub>5</sub>	5. Sum of 1 and 4.	6. Vol. of O <sub>2</sub> absorbed.
1/10 . . .	10	+ 61	+ 0·002	0·0	0·0	61	64
1/20 . . .	20	+ 111	+ 0·005	0·0	0·0	111	123
1/40 (1st stage)	40	+ 112	+ 0·001	0·0	0·0	112	132
1/46 (2nd stage)	40	+ 27	− 0·046	+ 0·064	204	231	174
1/80 . . .	80	+ 145	− 0·045	+ 0·056	179	324	347

We see from the above Table that in solution 1/10 the dissolved oxygen was not in sufficient quantity for the first stage of fermentation; hence putrefactive-fermentation had occurred.

But in the two following solutions it was; and in each the volume of carbon dioxide formed and the volume of oxygen absorbed were directly proportional to the quantity of fermentable matter originally present therein.

We further note that the time allowed for fermentation, 1/20 and 1/40, was only sufficient for the carbon fermentation, and that in neither had nitrogen fermentation commenced. We may therefore note this result, as in this experimentally aerobic conditions were maintained throughout, and yet no nitrification occurred; we may consider it as strong evidence in favour of the view that the fermentative changes really occur in two distinct stages—a view which other observers have maintained, and which I have assumed as true in the earlier part of the Paper.

It is important to note that the oxidation of ammonia to nitric acid is accompanied in solution 1/40 and inferentially in 1/80, by the formation of relatively small quantities of carbon dioxide.

The gas so formed was probably derived, as I shall show by later experiments, from the small quantities of oxidized organic substance which, as we shall find later, may under certain conditions be formed from the sewage-matters during the first stage of fermentation. The collected results for solution 1/40, and those for 1/80, show that when both stages are complete the quantities of carbon dioxide and nitric acid formed, and the volume of oxygen absorbed, were practically directly proportional to the quantity of fermentable matter originally present.

Putting the results in a quantitative form as before, we may say that 1000 volumes of sewage-water required 306 to 347 volumes of atmospheric oxygen for the complete fermentation, 125 to 132 volumes being required for the first stage, and 181 to 215 for the second stage.

The filtered sample of sewage from the Richmond Works, when similarly examined, gave the following results:—

## SERIES III.—COMMENCED JUNE 24TH, 1893.

TABLE V.—*Experiments with Sewage-water, which has been filtered through gravel filter-beds, and tap-water.*

Date of conclusion of Experiment.	Solution.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>	
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
1893 July 18	1 in 2	77.50	83.85	6.38	0.00	13.58	13.70	0.0085	0.0075	0.0018	0.0016	0.003	0.0045
	Differences, .	+ 6.35		- 6.38		.. ..		- 0.001		- 0.0002		+ 0.0015	
July 19	1 in 4	41.29	44.00	6.43	0.00	13.58	13.54	0.00425	0.0030	0.0009	0.00003	0.00155	0.0028
	Differences, .	+ 2.71		- 6.43		.. ..		- 0.00125		- 0.00087		+ 0.00125	
July 20	1 in 8	23.18	24.80	6.45	0.00	13.58	13.43	0.00213	0.0005	0.00045	0.00	0.000825	0.0028
	Differences, .	+ 1.62		- 6.45		.. ..		- 0.0016		- 0.00045		+ 0.00198	
July 24	1 in 16	14.12	15.11	6.46	3.41	13.58	13.54	0.00107	0.00025	0.000225	0.00	0.000402	0.0015
	Differences, .	+ 0.99		- 3.05		.. ..		- 0.00082		- 0.000225		+ 0.001	

REMARK.—All the solutions were quite free from odour after fermentation.

On multiplying each set of differences, so as to make them comparable one to another, and to the undiluted sample, we get:—

TABLE VI.

Solution.	Multiplier.	1. CO <sub>2</sub>	2.* N as N <sub>2</sub> O <sub>3</sub> oxidised to N <sub>2</sub> O <sub>5</sub>	3. O <sub>2</sub> = N <sub>2</sub> O <sub>3</sub> oxidised.	4.† N as N <sub>2</sub> O <sub>5</sub> from NH <sub>3</sub>	5. O <sub>2</sub> = NH <sub>3</sub> oxidized.	6. Sum of 1, 3, and 5.	7. Vol. of O <sub>2</sub> absorbed.
1/2	2	12.7	0.0004	0.32	0.0026	8.29	21.31	12.8
1/4	4	10.8	0.00348	2.78	0.0015	4.79	18.37	25.7
1/8	8	13.0	0.0036	2.86	0.0122	38.92	54.80	51.0
1/16	16	15.8	0.0036	2.88	0.0124	39.56	58.24	48.8

In the results given in these two Tables we have still further evidence that the volume of oxygen absorbed is practically proportional to the quantity of matters fermented; but in them we have also a more definite indication of the chemistry of at least one phase of nitrification than is observable in those of the two preceding series of experiments.

It may be taken for granted, I think, from the fact that nitrification had already been well established in this sample of filtered sewage-water before the commencement of my experiments, and from the general character of the results obtained, that the first stage of fermentation had been completed during the process of filtration to which it had been subjected at the Works from which it had been collected.

We have therefore in this series of experiments illustrations of the second stage of fermentation or true nitrification only; and it fortunately happens that the dilutions made up were just of sufficient strength to clearly illustrate the chemical changes which accompany nitric fermentation in polluted waters during their passage through land or artificial filters.

\* The numbers in this column have been calculated on the assumption that N as N<sub>2</sub>O<sub>3</sub>, shown to have been lost during fermentation, was completely oxidized to N<sub>2</sub>O<sub>5</sub>; and the figures in the next column have been calculated on the assumption that the oxidation of the N<sub>2</sub>O<sub>3</sub> took place according to the equation  $N_2O_3 + O_2 = N_2O_5$ .

This gives 0.8 c.cs. oxygen required to oxidize 0.001 grammes N as N<sub>2</sub>O<sub>3</sub> to N<sub>2</sub>O<sub>5</sub>.

† The numbers in this column give the N<sub>2</sub>O<sub>5</sub> less the loss of N<sub>2</sub>O<sub>3</sub> during fermentation, and it is assumed that these quantities were derived from ammonia. The numbers in the next column have been calculated on this assumption, as already explained. These four columns have been added simply for the purpose of approximate comparison.

It will be observed that the total N as NH<sub>3</sub> and N<sub>2</sub>O<sub>3</sub> lost in the case of each solution, except solution 1/4, is nearly equal in quantity to the N as N<sub>2</sub>O<sub>5</sub> formed.

It will be observed, on looking over the results given in the two foregoing Tables, that a fermentation of both nitrous acid and ammonia into nitric acid took place in each solution; that the fermentation of the nitrous acid in solutions 1/2 and 1/4 was incomplete, but complete in the remaining solutions, and that the ammonia was not completely oxidized in any of the solutions; and finally, that a decided quantity of carbon dioxide was formed during fermentation in each solution. This last noted product becomes of interest, and I may say of importance, when considered in relation to the recent researches of Dr. Munro, Professor P. F. Frankland and Mrs. G. C. Frankland, Mr. Warrington, and M. Winogradsky, already referred to, on the nitrification of ammonia in the absence of organic matters. These observers have all shown that the product of fermentation of ammonia in the absence of organic matter is invariably nitrous acid; and Winogradsky has supplied quantitative proof that the nitrous organism produces organic matters from inorganic materials, about thirty-five parts of nitrogen being oxidized for one part of carbon assimilated from ammonium carbonate. In the above tables we see that the nitric fermentation therein illustrated is accompanied by the formation of very distinct volumes of carbon dioxide, just as was noted in reference to the second experiment recorded in Table III. The question arises, what was the nature of the organic matter from which this gas was derived.

From the next series of experiments, which I shall have to describe, we shall find evidence which goes to show that the organic matters which undergo change during a second stage fermentation of the character above illustrated, have themselves been formed during a first stage fermentation under aërobic conditions.

The results recorded in Table V. for solution 1/4 require special reference, as they appear to be exceptional when compared with those afforded by the other solutions of the series.

Thus, relatively less carbon dioxide was formed in it; and the total inorganic nitrogen found after fermentation was decidedly less than that present before fermentation, the quantities being 0.00583 and 0.00670 parts per 1000 respectively. On the other hand, the volume of dissolved oxygen actually absorbed was relatively similar to that absorbed in the other solutions.

The exceptional results here apparent are not, I consider, due to experimental errors; they are rather to be ascribed to a difference of type, or phase, of a second stage fermentation.

In the other solutions of this series we have apparently one and the same type of nitrogen fermentation taking place, viz. a fermentation of  $\text{NH}_3$  and  $\text{N}_2\text{O}_3$  into  $\text{N}_2\text{O}_5$ , accompanied by a fermentation of organic matter. In the solution under discussion we have also this type of fermentation occurring, but, apparently, in addition, another type, viz. the oxidation of ammonia, and possibly also of

nitrous acid to nitric acid, accompanied by a fixation of small quantities of inorganic materials, presumably to form organic matter, as Winogradsky has shown takes place in the nitrous fermentation of ammonia in the absence of organic matter.

That a number of variations are possible during the fermentation of  $\text{NH}_3$  and  $\text{N}_2\text{O}_3$  in the presence of organic matters that have undergone the first stage of fermentation, I shall show by further experiments.

Regarding the method of examination, illustrated by these experiments, simply as an analytical probe, it is quite evident that it affords the means of differentiating the character of fermentable matters in waters, and approximately estimating their amount, to a degree quite beyond the power of any other method. Thus, when the samples of raw and filtered sewage water were examined by the methods commonly used, the following results were obtained:—

*Constituents expressed as parts per 1000.*

	Untreated Sewage-Water.	Filtered Sewage-Water.
Free Ammonia, . . . . .	0·0475	0·017
Albuminoid Ammonia, . . . . .	0·005	0·0012
Oxygen absorbed from standard $\text{KMnO}_4$ acting in the cold for three hours, . . . . . )	50·2 c.cs.	16·2 c.cs.

It is impossible, of course, to draw any conclusion as to the character of the organic matters in either sample from the above results. They do not even give any definite idea of the actual quantities of the organic matter in the samples, neither do they afford the means of estimating the influence which such liquids would exert in river-water when discharged into it. While, on the other hand, the results afforded by the experiments of Series II. and III., above described, give complete answers to each of these points. They show that, on the one hand, the untreated sewage-water underwent a first stage fermentation before true nitrification, and therefore contained matters which would set up putrefaction if the supply of atmospheric oxygen to all parts were restricted, and that, on the other hand, the filtered sewage-water did not, but nitrification alone, and that therefore putrefaction was impossible in the liquid, even when the supply of dissolved oxygen was restricted. They further show the exact volumes of atmospheric oxygen required for the complete fermentations in the untreated water, and that required for the complete fermentation in the filtered water, giving at the same time the quantities and character of the products of fermentation.

The next series of experiments which I have to describe were made with solutions of definite chemical compounds, and it will, I think, be also of advantage to discuss them, not in their chronological order, but in such a way as may best serve to bring out the points I am anxious to establish in this research.

I will therefore first describe a series of experiments carried on with a solution of asparagine and crystallized potassium sodium tartrate. A strong solution was made up, containing 0·066, and 0·141 grammes of these bodies, respectively; also 0·1 gramme of potassium phosphate per litre of solution; only two dilutions were made from this, it being determined to commence the experiments with a considerable quantity of each solution in several bottles, and if necessary, after determining the products of a fermentation, to re-aërate and analyse, and to put up again in smaller bottles for a further fermentation. It was hoped by this means to gain, more especially, definite information on the question whether ammonia was formed during the first stage fermentation of a nitrogenous substance, in the continued presence of an excess of dissolved oxygen or not.

There were other reasons for making this modification in detail of the method of examination, which will appear as the results of the experiments are considered.

The full particulars of these experiments are given in the subjoined Tables VII. and VIII.

[TABLES VII. AND VIII.]

SERIES IV.—COMMENCED MARCH 6, 1894.

TABLE VII.—*Experiments with Asparagine and Sodium Potassium Tartrate.*

Solution A contained 0.066 grams asparagine,  
0.141 " sodium potassium tartrate, cryst., } per litre.  
0.1 " potassium phosphate.

No. of experiment.	Date of commencement and of conclusion of experiment.	Nature of Experiment.	CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>	Remarks.
1	March 6, 1894,	Solution A, as above (in tap-water), . . .	11.21	7.86	15.93	0.0	0.0	0.0001	
	" 12, "	Same after fermentation, . . .	26.73	0.05	16.13	0.0093?	0.0	0.0	Liquid very turbid, but free from odour.
	" 12, "	Differences, . . .	+ 15.52	- 7.81	—	+ 0.0093?	—	—	
2	" 12, "	Remainder of preceding solution, after fermentation, re-aerated, = A', . . .	26.62	7.36	15.14	0.0095?	0.0	0.0	Ditto.
	" 13, "	A' after fermentation, . . .	37.16	1.52	15.30	0.0108?	0.0	0.0	
	" 14, "	Another bottle of A' after fermentation from March 12, . . .	40.15	0.05	15.16	0.0102?	0.0	0.0	Ditto.
	" 14, "	Differences, . . .	+ 10.54	- 5.84	—	+ 0.0013?	—	—	
	" 14, "	Differences, . . .	+ 13.53	- 7.31	—	+ 0.0007?	—	—	
3	" 14, "	Remainder of solution A' (March 14) diluted with equal volume of distilled water and aerated = A'/2, . . .	20.62	7.81	16.11	0.0032	0.0	0.0	Faint sour odour; turbid.
	" 19, "	Same after fermentation, . . .	32.21	1.72	15.92	0.0045	0.0	0.0	Ditto.
	" 19, "	Another bottle of A'/2 after fermentation, II. Differences, . . .	32.01	1.56	15.89	0.0038	0.0	0.0	
	" 19, "	Differences, . . .	+ 11.59	- 6.09	—	+ 0.0013	—	—	
	" 19, "	Differences, . . .	+ 11.39	- 6.25	—	+ 0.0006	—	—	
4	" 19, "	Remainder of liquid from two preceding analyses, mixed and aerated, . . .	29.06	7.56	15.60	0.0030	0.0	0.0	No distinct odour.
	April 12, "	Same after fermentation, . . .	36.75	0.00	15.40	0.0056	0.0	0.0	
	" 12, "	Differences, . . .	+ 7.69	- 7.56	—	+ 0.0026	—	—	
5	" 12, "	Remainder of preceding solution re-aerated, Same after fermentation, . . .	31.42	7.04	13.98	0.004	0.0	0.0	Quite free from odour.
	August 1, "	Differences, . . .	35.22	0.0	14.10	0.0044	0.0015	0.0	
	" 1, "	Differences, . . .	+ 3.80	- 7.04	—	+ 0.0004	+ 0.0015	—	
6	" 1, "	Remainder of preceding solution diluted with an equal bulk of distilled water and aerated, . . .	17.033	6.11	12.67	0.0022	0.0009	0.0	
	Jan. 4, 1895,	Same after fermentation, . . .	16.69	0.07	12.55	0.0	trace	0.002	
	" 14, "	Another bottle of same after fermentation, II. Differences, . . .	16.79	0.05	12.63	0.0	0.00016	0.00204	
	" 14, "	Differences, . . .	- 0.34	- 5.94	—	- 0.0022	- 0.0009	+ 0.002	
	" 14, "	Differences, . . .	- 0.24	- 5.96	—	- 0.0022	- 0.00074	+ 0.00204	

SERIES IV.—continued.

TABLE VIII.—Experiments with solution A diluted with tap water.

No. of experiment.	Date of commencement and of conclusion of experiment.	Nature of Experiment.	CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>	Remarks.
1 a	March 6, 1894,	Solution A from Table VII., diluted with tap-water in the proportion of 1 : 9 vols.,	4.65	7.86	15.93	0.0	0.0	0.0001	Slightly turbid, no odour.
	" 15, "	Same after fermentation, . . . .	9.32	4.52	15.75	0.0008	0.0	0.0001	
		Differences, . . . .	+ 4.67	- 3.34	—	+ 0.0008	—	—	
	" 15, "	Remainder of preceding solution aerated, .	9.05	7.35	15.64	0.0008	0.0	0.0001	
2 a		Same after fermentation, . . . .	12.28	2.06	15.47	0.0	0.0	0.0015	
	May 17, "	Differences, . . . .	+ 3.03	- 5.19	—	- 0.0008	—	+ 0.0014	
3 a	March 6, "	Solution A from Table VII., diluted with tap-water in the proportion of 1 : 19 vols., I.	4.29	7.86	15.93	0.0	0.0	0.0001	
	" 20, "	Same after fermentation, . . . . II.	6.86	5.63	15.94	0.0008	0.0	0.0001	
		Differences, . . . .	+ 2.57	- 2.23	—	+ 0.0008	—	—	
	" 20, "	Remainder of preceding solution immediately transferred to a smaller bottle, and after further fermentation again analysed,	8.04	4.02	15.86	trace	0.00048	0.00042	
4 a	April 30, "	Differences (from II.), . . . .	+ 1.18	- 1.63	—	- 0.0008	+ 0.00048	+ 0.00032	

Continuing the train of thought suggested by the three preceding series of experiments, we may note in the first instance that the experiments recorded in the Tables VII. and VIII. afford further evidence that the fermentation, which may take place in a natural water containing unfermented matters in solution, under aërobic conditions, does so in two distinct stages.

That ammonia, and not nitrous or nitric acid, is formed during the first stage of fermentation of nitrogenous organic matters, even in the continued presence of an excess of dissolved oxygen, is clearly proved by experiments 1, 2, and 3, in Table VII., and by 1*a* and 3*a* in Table VIII.

We may note also that experiment 6, recorded in Table VII., affords another, but more definite, illustration of that phase of nitrification, which had apparently been set up in solution 1/4 of Series III., and which, as I stated above, might afford an explanation of the exceptional results afforded by this solution. From the results recorded of this experiment 6, we see that an oxidation of ammonia, and possibly also of nitrous acid, took place, and that at the same time small quantities of carbon dioxide, and also of ammonia, or of nitrous acid, or both, were fixed, no doubt, from Winogradsky's experiments, to form organic matter. It is interesting to observe that in each experiment here quoted, the quantity of nitric acid formed is practically exactly equivalent to that of ammonia lost, and that the difference between total inorganic nitrogen before and after fermentation corresponds with the loss of nitrous nitrogen during fermentation. It is just possible from this, that, in nitric fermentation, nitrous acid may enter into the reaction by which organic matters are formed from inorganic materials. But this requires further experimental investigation.

Another point to be noted in reference to these two experiments is, that in one (solution 1/4, Series III.) the volume of dissolved oxygen absorbed is decidedly in excess of that theoretically required for the oxidation of ammonia to nitric acid, while it is a little less in the other experiment (6). This difference may have been due to a difference in character of the organic matter present in the two solutions, since there can be no doubt, from experiments I have yet to describe, that organic matters which have themselves undergone change during a previous first stage fermentation, exercise a marked influence on the subsequent stage of fermentation, or true nitrification, and that these fermented organic matters vary very much in chemical character, so far as nitrification is concerned, I hope to illustrate by further experiments.

The quantities of carbon dioxide, and inorganic nitrogen fixed in experiment 6 are small, so small, in fact, that the errors attending their determination are unfortunately much too appreciable to warrant an attempt to draw definite conclusions as to any quantitative relationship which may exist between them.

The modification in the method of experimenting employed for the Series IV.,

renders it possible, it will be seen, to examine the intermediate steps of both the first and the second stage fermentations, and to obtain important results.

To confine attention, in the first instance, to the intermediate steps of the first-stage fermentation recorded in experiments 1, 2, 3, and 4, in Table VII., we notice that during the steps represented by the first three experiments much larger volumes of carbon dioxide were formed than could be accounted for on the assumption that the fermentation in each case consisted of a simple oxidation effected through the agency of the active organisms present in the solution, upon a quantity of the organic matters equivalent to the volume of dissolved oxygen absorbed. Thus, the calculated ratio of carbon dioxide formed to that of the oxygen absorbed by the complete oxidation of the asparagine to carbon dioxide, water, and ammonia, and of potassium sodium tartrate, to its ultimate products of oxidation, are, respectively, as 1.33 : 1, and 1.6 : 1, and if equivalent proportions of these two substances be oxidized at the same time, then the ratio becomes 1.465 : 1. On the other hand the ratios of the volumes of carbon dioxide actually formed to those of oxygen absorbed, in experiments 1, 2, and 3, are as 2 : 1, 1.85 : 1, and 1.86 : 1, respectively. While for experiment 4 this ratio drops nearly to 1 : 1.

It is quite evident, therefore, that, notwithstanding the fact that the earlier steps of the first stage fermentation represented by experiments 1, 2, and 3, were attended throughout with aërobic conditions, changes other than those which would result from simple oxidation by the dissolved oxygen absorbed, must have been set up in the organic matters present in the solution. These changes seem to have been complete by the end of the step represented by experiment 3, for the ratio of carbon dioxide formed to oxygen absorbed during the next stage represented by experiment 4, drops suddenly to 1 : 1.

This ratio is so low that we are justified in believing that the organic matters which underwent fermentation during this last step were not unfermented portions of the matters originally present, but were themselves the products of the changes which we have seen must have been set up during the earlier steps of fermentation represented by experiments 1, 2, and 3.

In experiment 5 it appears we have illustrated the completion of the first-stage fermentation, and the commencement of the second stage. Judging from the quantities of carbon dioxide, ammonia, and nitrous acid formed, and oxygen absorbed, it is probable that nearly the whole of the first-named product should be referred to the first stage. Thus the volume of oxygen theoretically required to oxidize 0.0015 grammes nitrogen as ammonia to nitrous acid equals 3.585 c.cs. Deducting this from the volume of oxygen shown by the experiment to have been absorbed, we get 3.455 c.cs., while the volume of carbon dioxide formed was 3.8 c.cs. These volumes approach sufficiently near in proportion to

those which are recorded for the preceding experiment 4, to allow us, I think, to regard them as indicating the volume of oxygen absorbed, and of carbon dioxide formed during the conclusion of the first-stage fermentation, without introducing serious errors.

If this assumption be allowed, we can sum together the volumes of carbon dioxide formed, and of oxygen absorbed, during each of the steps of the first-stage fermentation represented by experiments 1, 2, 3, 4, and 5, and obtain the total volume of carbon dioxide formed, and of oxygen absorbed, by the complete first-stage fermentation of the two organic substances originally present in solution A. Thus:—

—	CO <sub>2</sub>	O <sub>2</sub>
Experiment 1, . . . . .	15.52	7.81
„ 2, . . . . .	13.53	7.31
„ 3 (× 2), . . . . .	22.98	12.34
„ 4 (× 2), . . . . .	15.38	15.12
„ 5 (× 2), . . . . .	7.6	6.91
Totals, . . . . .	75.01	49.49

The total volumes of carbon dioxide formed, and of oxygen absorbed, at the conclusion of the first-stage fermentation, we then see are 75.01 and 49.49 c.cs., respectively. The ratio of these numbers to one another is as 1.52 : 1, which approximates to the volumes of carbon dioxide and oxygen, which, as I stated above, would be respectively formed and absorbed, were the two substances present in solution A directly oxidised completely to the ultimate inorganic products, carbon dioxide, water, and ammonia, viz. 1.465 : 1.

It appears then, from this, that notwithstanding the fermentative changes which were set up in solution A other than those which would result from simple oxidation during the earlier steps of the first-stage fermentation, the total volume of carbon dioxide formed, and of oxygen absorbed, resulting from the complete first-stage fermentation of the two substances present in the solution, bear approximately the same proportion to one another as if the fermentation had consisted throughout of a simple and direct oxidation by the oxygen absorbed acting upon an equivalent quantity of the mixture of the two substances originally present in the solution.

On turning to the results of the experiments with the dilute solutions of A, recorded in Table VIII., we observe that dilution seems to exert a very decided

influence on the course, more especially of the earlier steps of the first stage fermentation.

Thus, from the first experiment with solution A diluted to 1 in 10, it is probable from the quantities of carbon dioxide and ammonia formed, that the first stage had run through but little more than half its course, but notwithstanding this, the ratio of carbon dioxide formed to oxygen absorbed is as 1.4 : 1.

The influence of dilution is still more markedly shown by the results recorded from experiment 3a with solution A diluted to 1 in 20. This experiment had been allowed a decidedly longer time for fermentation; and it seems probable from the quantity of ammonia formed, that the first stage had nearly run its complete course.

The ratio between the above two gases, respectively, formed and absorbed becomes as 1.15 : 1.

It seems then from these two experiments that in the fermentative changes that were set up in the earlier steps of the first-stage fermentation of these dilute solutions, the dissolved oxygen took part to a degree increasing with the dilution, and that the resulting compounds were in all probability more highly oxidized than those formed during similar stages of fermentation in the undiluted solution A.

On examining the results of the further experiment (4a) with the more dilute solution, recorded in Table VIII., we find evidence to show that the organic matters which are formed during the first stage in so dilute a solution, may themselves undergo further change during nitrification, and give rise to the formation of carbon dioxide coincidentally with the oxidation of ammonia.

But it is of importance to note that from the quantity of nitrous and nitric acids formed, and of oxygen absorbed, in experiment 4a, the formation of this carbon dioxide could not have been attended with the absorption of any but a relatively extremely small volume of oxygen.

On turning to the results obtained from the second experiment (2a), with the less dilute solution, we find evidence of a similar nature recorded.

It may be urged, and rightly so, that from the way in which the second experiment (4a) with the more dilute solution of A was carried out, the volume of oxygen absorbed during fermentation, recorded in Table VIII., is probably too low.

Unfortunately the quantity of liquid left from the experiment 3a was not sufficient to allow of re-aëration and analysis in the usual way before re-bottling; hence the necessity of carrying out experiment 4a in the manner described in the Table. During the operation of transferring the liquid to a smaller bottle, it, no doubt, absorbed a small quantity of oxygen from the air. This would not, of

course, be accounted for by the results recorded in the Table, and therefore the objection that the volume of oxygen given as absorbed during fermentation is probably too low.

I feel confident, however, from experiments which have, from time to time, been made in the course of my work, and which have given me the means of estimating the error attending the operation here described, with a liquid containing so much dissolved oxygen as this one did at the time of re-bottling, that the error certainly does not exceed 0.5 c.c.

It has already been pointed out, when discussing the results of the experiments with the filtered sewage-water, recorded in Table V., that the second-stage fermentation was accompanied by the formation of a decided quantity of carbon dioxide. It therefore appears from this that filtration affects the earlier steps of the first stage in much the same way that dilution does.

It is of importance to note in relation to the objects which I have had in view in the carrying out of this investigation, that, notwithstanding the variations in the chemical changes which these experiments with the solution of asparagine and tartrate have shown to be possible during the intermediate steps of fermentation, according as the quantities of fermentable organic matters and of atmospheric oxygen are varied, relatively to one another, the total quantities of carbon dioxide formed, and of oxygen absorbed, during the whole course of fermentation may, for practical purposes, be taken as independent of such variations, provided that aërobic conditions be maintained throughout the complete course of fermentation.

This will be readily seen when the products of the complete fermentation in each dilute solution are multiplied so as to render them comparable with those obtained from the undiluted solution A, thus:—

Solution.	Experiment.	CO <sub>2</sub>	O <sub>2</sub> = to N <sub>2</sub> O <sub>3</sub>	O <sub>2</sub> = to N <sub>2</sub> O <sub>5</sub>	O <sub>2</sub> absorbed.
A/10	1a (× 10), . . . .	46.7	0.0	0.0	33.4
„	2a (× 10), . . . .	30.3	0.0	44.66	51.9
	Totals, . . . .	77.0	0.0	44.66	85.3
A/20	3a (× 20), . . . .	51.4	0.0	0.0	44.6
„	4a (× 20), . . . .	23.6	22.94	20.42	32.6
	Totals, . . . .	75.0	22.94	20.42	77.2

We find from the above Table that the total volumes of carbon dioxide evolved during the whole course of fermentation in the dilute solutions, when multiplied

so as to render them comparable to the volume of the same gas evolved by the undilute solution A, are practically equal to one another, and also to the volume evolved during fermentation in the undiluted solution. They are respectively equal to 77, 75, and 75 c.cs.

With reference to the oxygen absorbed during fermentation, it will be seen that, in experiment 2*a*, the second stage was complete; and the total volume of oxygen absorbed during both the two stages, when multiplied by 10 for the purpose already explained, amounts to 85.3 c.cs.

In experiment 4*a* the oxidation of the nitrogen was not quite complete.

If, however, we add to the volume of oxygen given in the above Table, viz. 77.2 c.cs., the volume of oxygen theoretically required to oxidize the nitrous acid formed in this experiment to nitric acid, viz. 7.68 c.cs., we get a total volume 84.88 c.cs., which approximates to that given for the less dilute solution.

The experiments with solution A do not, unfortunately, give the means of estimating the oxygen absorbed during the second stage fermentation.

The carbon, both in the asparagine and tartrate employed in these experiments, was carefully determined by combustion in the ordinary way before commencing these experiments. The total organic nitrogen in solution A was also determined by Kjeldahl's method.

From these determinations it was found that the organic carbon per litre of solution was as follows:—

0.066 grammes asparagine	= 0.0225 grammes carbon,	} equivalent to 85.37 c.cs. CO <sub>2</sub> .
0.141 „ tartrate	= 0.0234 „ „	
Organic nitrogen	= 0.0139 „ per litre of solution.	

As already shown, the volume of carbon dioxide formed by the complete fermentation of these quantities of asparagine and tartrate may be taken as equal to 75 c.cs.

This volume approximates sufficiently close to 85.37 c.cs., the volume which would be formed by the complete oxidation of similar quantities of the same substances, to warrant us in regarding it for purposes of water analyses, as a quantitative expression of the amount of substances originally present in the water.

The solutions experimented with contained minute quantities of peaty colouring matters, besides the substances added. These matters, however, probably underwent little, if any, change.

I may here note that the volume of carbon dioxide formed by the fermentation of the peaty matters in the tap-water employed for making up the dilutions may be taken as about 1 c.c. per litre (see p. 561).

With reference to the quantities of ammonia, nitrous and nitric acids formed during fermentation, we observe that in experiment 3*a*, the quantity of nitrogen recorded as ammonia is approximately equal to that of the organic nitrogen originally present. The same may be said of the nitric nitrogen recorded in experiment 2*a*, and of the nitrous and nitric nitrogen recorded in experiment 4*a*. The ammonia determinations recorded in experiments 1 and 2 in Table VIII. are unreliable. They are probably much too high owing to the possibility, which was unfortunately recognised too late, that although the asparagine itself suffered no appreciable decomposition, when the original solution A was distilled in the presence of borax, the compounds formed from it by partial fermentation would, and thus give rise to an evolution of ammonia which did not exist as such in the original solution.

To avoid this possible source of error as much as possible, it was determined to nesslerize small portions of the solutions diluted with as large volumes of pure water as possible. The ammonia determinations recorded for all experiments after No. 2, both as regards the solution A itself, and with the diluted solutions made from it, were obtained by this means.

On summing up the results obtained from this series of experiments, we find they afford additional evidence in support of the conclusions which it was possible to draw from those afforded by the three preceding series of experiments with sewage waters, viz. that, when the dissolved oxygen is in excess relatively to the fermentable matter present in a water, the quantities of carbon dioxide and nitric acid formed, and of oxygen absorbed, *after complete fermentation*, may be taken as directly proportional to the quantities of the fermentable matters originally present in the water.

We have also evidence in these results which goes to show that the quantities of carbon dioxide and nitric acid formed on complete fermentation may be taken, for the purpose of water analysis, as quantitative expressions of the fermentable organic carbon, and of the total organic and inorganic nitrogen originally present in the water. This last conclusion is also supported by all the preceding series of experiments.

We see, however, from the results obtained from these solutions of known strength and composition, that the conditions of experimenting must be strictly laid down, and adhered to if definite conclusions are to be drawn, because:—

1. We learn that the volume of carbon dioxide evolved during a first stage fermentation, relatively to a given volume of oxygen absorbed, may vary, even under continued aërobic conditions, with the relative quantities of fermentable organic matters, and the dissolved oxygen originally present in the water.

When the first stage of fermentation is carried on under conditions such as obtained in the experiments with solution A, viz. the presence of a considerable excess of fermentable organic matters, relatively to the oxygen present, during the earlier steps of the fermentation, we find that the organic carbon present in the solution may be almost completely oxidized to carbon dioxide during the said first stage fermentation, and that little or none of this gas is formed during the after-fermentation of the ammonia in the same solution.

When, on the other hand, the conditions at the commencement are reversed, viz. the oxygen is large relatively to the fermentable matters present, we see from the experiments with the dilutions of solution A, and from those with the filtered sewage-water used in Series III., that the oxidation of the organic carbon to carbon dioxide during the first stage may be far from complete before the commencement of the second stage of fermentation, but that the organic matters undergo, partially at least, an intermediate stage of oxidation, and that the oxidized matters which result suffer further change during nitrification, and give rise to the formation of decided volumes of carbon dioxide.

2. We also learn that, under the same conditions, not clearly defined by the experiments in question (solution 1/4, Series III., and exp. 6, Series IV.), carbon dioxide and ammonia, and possibly also nitrous acid, may become fixed, even in the presence of organic matters (fermented) presumably to form organic matter.

At the same time we are warranted in believing, from the results hitherto considered, that when a number of dilutions of a water under examination are experimented with, as was done with the samples of sewage-waters above examined, a series of results are obtained which reveal at once an exceptional course of fermentation, such as that shown by solution 1/4 in Series III., and from which definite and valuable conclusions may be drawn as to the character of the organic matters present.

The experiments I have next to quote were made with a view more particularly of gaining further evidence in addition to that already given, as to the relationship between the quantity of inorganic nitrogen formed by the fermentation of sewage-waters under continued aërobic conditions, and that of the total organic nitrogen originally present. These experiments were made with three samples of partially purified sewage, from the same sewage-works. Each sample was filtered to separate matters in suspension, and diluted with tap-water in the proportion of 1 to 49, respectively. The dilutions were marked for reference, S<sub>1</sub>, S<sub>2</sub>, and S<sub>3</sub>.

The total organic and ammoniacal nitrogen in each dilution was determined at the time of bottling, by Kjeldahl's method, and the ammoniacal nitrogen by direct nesslerization.

The following results were recorded:—

S <sub>1</sub>	.	.	.	Organic nitrogen per 1000 c.cs. of solution = 0·0016 grammes.
S <sub>2</sub>	.	.	.	" " " " " " = 0·0020 "
S <sub>3</sub>	.	.	.	" " " " " " = 0·0006 "

The particulars of the experiments are recorded in the subjoined Table:—

TABLE IX.

Solution.	Date.	CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>
S <sub>1</sub> . .	Nov. 16, 1894, .	5·89	6·77	16·64	0·0012	0·0	0·0002
" . .	Jan. 16, 1895, .	10·48	3·62	15·50	0·0023	trace.	0·0002
	Differences, .	+ 4·59	- 3·15	- 1·14	+ 0·0011	—	0·0
S <sub>2</sub> . .	Nov. 16, 1894, .	7·85	7·35	16·10	0·0036	0·0	0·0002
" . .	Jan. 21, 1895, .	15·18	0·15	15·16	0·0046	0·00112	0·0004
	Differences, .	+ 7·33	- 7·23	- 0·94	+ 0·001	+ 0·00112	+ 0·0002
S <sub>3</sub> . .	Nov. 17, 1894, .	7·13	7·44	16·06	0·001	0·0	0·0004
" . .	Jan. 24, 1895, .	8·63	2·46	15·18	0·0001	0·0	0·0018
	Differences, .	+ 1·50	- 4·98	- 0·88	- 0·0009	—	+ 0·0014
Tap-water	Nov. 17, 1894, .	5·01	7·80	15·96	0·0	0·0	0·0002
" I.	Jan. 23, 1895, .	5·11	7·72	16·01	0·0	0·0	0·0002
" II.	March 4, 1895, .	5·20	7·60	16·03	0·0	0·0	0·0002

So far as the relationships between the quantity of organic nitrogen originally present in a water, and that of the inorganic nitrogen which finally results from its complete fermentation are concerned, the above results do not do more than afford additional evidence of the general conclusions which those of the preceding experiments have yielded, viz. that much the greater portion of the fermentable organic nitrogen in a water, is converted into inorganic nitrogenous bodies. It is impossible, it is to be feared, to obtain more accurate results, with the present known method for the nitrogen determinations, whereby any more definite inference as to this relationship can be drawn than the general one just given, since the errors attending the various determinations required become very much too appreciable.

Notwithstanding, however, this want of precision in the nitrogen determination, the experimental details quoted in the above Table IX., when considered

together afford most valuable information, as to the character and quantity of fermentable matters present originally in the respective solutions experimented with.

Thus, for each solution we have a loss of oxygen determined with great accuracy. That recorded for the solution  $S_3$  gives the volume of this gas required for complete fermentation, while the loss recorded for each of the other two solutions is seen to cover only a partial fermentation of the matters present. The volume of oxygen required for the complete fermentation of these two solutions could have been determined by additional experiments; and with the data which would have been thus obtained, we could have contrasted the three solutions as to the total volume of oxygen required for complete fermentation, or, what is of much greater importance, as we have seen already, in the analysis of water polluted with such matters as sewage, we could have distinguished the volumes of oxygen required for each of the two stages of fermentation in each.

#### Fixation of Atmospheric Nitrogen.

There are other results which these experimental solutions have furnished, to which the greatest interest will be attached, viz. those afforded by the atmospheric nitrogen determinations. These show that very distinct quantities of that gas were absorbed during fermentation in each solution, and they are, so far as I know, the first recorded observations showing directly that atmospheric nitrogen may be absorbed during bacterial fermentation.\*

On reference to the Table IX. it will be seen that the loss of nitrogen was 1.14, 0.94, and 0.88 c.cs., for the three solutions respectively. These numbers are much too high to ascribe to experimental errors, and in proof of this I have appended to the results obtained with the experimental solutions those afforded by samples of the tap-water employed for making the dilutions, which were bottled and kept under exactly similar conditions.

In reference to these experiments with the tap-water, I may note that they afford additional evidence to that already given, that the minute quantity of peaty matters contained therein really undergo slow fermentation to a degree, which begins to be indicated by the method of observation which I have employed in these experiments, after about four months' keeping.

\* Since the above was written, M. Winogradsky has published a paper describing the isolation and properties of a butyric ferment, which has the power of fixing free nitrogen.—Arch. Sciences Biol. 1895, 3, 297–352; also Chem. Soc. Jour. Abstr. 68, 283.

**Fixation of Carbon Dioxide and of Ammoniacal Nitrogen.**

There is yet one further point of interest which I have to mention in reference to these solutions, namely, an additional experiment which I made with the portion of the solution  $S_2$ , which remained after the various analyses had been made on the day recorded, viz. January 21st. It will be seen on reference to Table IX. that the solution on that date was very similar in composition, so far as the probable character of the organic matters, and also so far as the composition of the inorganic nitrogenous bodies it contained, was concerned; to those in which we have already observed a fixation of carbon dioxide and inorganic nitrogen to have occurred during fermentation, viz. in solution 1/4 and in experiment 6, recorded in Tables V. and VII. respectively. In order to ascertain whether a similar action would take place during a further fermentation of solution  $S_2$ , the remainder mentioned above was re-aërated and bottled, and analysed before and after keeping, with the following results:—

Date.	CO <sub>2</sub> .	O <sub>2</sub> .	N <sub>2</sub> .	N as NH <sub>3</sub> .	N as N <sub>2</sub> O <sub>3</sub> .	N as N <sub>2</sub> O <sub>5</sub> .
January 25, 1895, . .	10·67	7·6	15·22	0·0045	0·00128	0·0006
March 1, 1895, . .	9·90	0·0	15·25	0·0027	0·00128	0·00182
Differences, . .	- 0·76	- 7·7	—	- 0·0018	—	+ 0·00122

From the results just given, it will be seen that a fixation of carbon dioxide and ammoniacal nitrogen really occurred, as was anticipated during further fermentation, but that apparently the nitrous nitrogen, unlike that in the case of the two solutions above referred to, did not take part.

Before passing on to describe my experiments with waters containing considerable quantities of peaty matter, I will give some further experimental results, which will be found to support the general conclusions which have been drawn from those already considered.

The full details of the experiments are recorded in the subjoined Tables:—

## SERIES V.—COMMENCED 27TH JUNE, 1894.

TABLE X.—*Experiments with Diluted Sewage-Water.*

No. of Experiment.	Date of Commencement, and of Conclusion of Experiment.	Nature of Experiment.	CO <sub>2</sub> .	O <sub>2</sub> .	N <sub>2</sub> .	N as NH <sub>3</sub> .	N as N <sub>2</sub> O <sub>3</sub> .	N as N <sub>2</sub> O <sub>5</sub> .	REMARKS.
1	June 27, 1894	1 volume of sewage-water, diluted with 2 volumes of distilled water, and aerated,	76.80	4.50	13.85	0.02	0.0	0.0	Odour slightly offensive.
	Aug. 30, "	Same, after fermentation, . . .	104.96	0.00	13.68	0.022	0.0	0.0	Very offensive odour of putrefaction and SH <sub>2</sub> .
		Differences, . . .	+ 28.16	- 4.50	..	+ 0.002	..	..	
2	Aug. 30, "	1 volume of remainder of preceding solution, after fermentation, diluted with 2 volumes of distilled water, and aerated,	33.79	5.37	14.42	0.008	0.0	0.0	Distinct odour of SH <sub>2</sub> .
	Nov. 21, "	Same, after fermentation, . . .	38.62	0.0	14.22	0.012	0.0	0.0	Offensive odour of putrefaction and SH <sub>2</sub> .
		Differences, . . .	+ 4.83	*- 5.37	..	+ 0.004	..	..	
3	Nov. 21, "	Remainder of preceding solution, diluted with three times its volume of distilled water,	8.94	7.39	15.17	0.003	0.0	0.0	
	Jan. 12, 1895	Same, after fermentation, . . .	9.54	1.34	15.02	0.0	0.0	0.0015	Quite free from odour.
		Differences, . . .	+ 0.60	- 6.05	..	- 0.003	..	+ 0.0015	

\* This volume of oxygen was probably not all consumed by the fermentative process. SH<sub>2</sub> and other reduced products of putrefactive fermentation were present at the commencement of the experiment, and a portion of the oxygen was, no doubt, taken up by the direct oxidation thereof.

## SERIES VI.—COMMENCED 30TH DECEMBER, 1892.

TABLE XI.—*Experiments with Potassium Sodium Tartrate.*

Solution IV. contained 0.1 grammes carbon as potassium sodium tartrate (cryst),  
 0.1 " " sodium carbonate,  
 0.1 " " potassium phosphate,

}  
 per litre.

Date of conclusion of Experiment.	Solution.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>	
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
Aug. 10, 1893	IV. Differences, . .	22.42 + 18.42	40.84	8.40 - 8.40	0.00	16.72 ..	16.87 ..	0.0 + 0.0001	0.0001 - 0.0001	0.0001 - 0.0001	0.00 0.0001
April 4, 1894	IV./5 Differences, . .	7.49 + 25.06	32.55	8.40 - 8.40	0.00	16.72 ..	16.47 ..	0.0 + 0.0005	0.0001 - 0.0001	0.0001 - 0.0001	0.00 0.0001
April 4, "	IV./10 Differences, . .	5.62 + 17.55	23.17	8.40 - 8.40	0.00	16.72 ..	16.48 ..	0.0 + 0.0004	0.0001 - 0.0001	0.0001 - 0.0001	0.00 0.0001
Dec. 21, "	IV./40 Differences, . .	4.23 + 5.23	9.45	8.40 - 6.46	1.94	16.72 ..	16.25 ..	0.0 ..	0.0001 + 0.0005	0.0001 + 0.0005	0.0006 0.0005
Dec. 21, "	IV./80 Differences, . .	3.99 + 3.85	7.84	8.40 - 2.91	5.49	16.72 ..	16.47 ..	0.0 ..	0.0001 + 0.0005	0.0001 + 0.0005	0.0006 0.0005

REMARKS.—The ammonia formed during fermentation in dilutions IV./5 and IV./10 was derived, no doubt, from the nitrate, and possibly also, in the case of the latter dilution, from the peat in the tap-water.

Owing to the length of time (just two years) the dilutions IV./40 and IV./80 were kept, there can be little doubt, since an excess of oxygen was present in each, that the peaty matter in the tap-water employed for their preparation underwent fermentation as well as the tartrate. This will account for the nitrates formed in these solutions, and also for the relatively large volumes of carbon dioxide found therein, compared with the less dilute relations. (See Table XIV.)

The considerable differences shown by the atmospheric nitrogen determinations in the case of the dilute solutions, may be, partially, at least, due to fixation, but this may also be due to greater errors than those commonly arising, owing to the very long time the solutions were kept.

SERIES VII.—COMMENCED 30TH DECEMBER, 1892.

TABLE XII.—*Experiments with Potassium Sodium, Tartrate, and Ammonium Chloride.*

Solution B contained 0·0468 grammes carbon as potassium sodium tartrate (cryst.),  
 0·01                   "           nitrogen as ammonium chloride,  
 0·10                   "           sodium carbonate,  
 0·10                   "           potassium phosphate,

} per litre.

Date of conclusion of Experiment.	Solution.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>		N as N <sub>2</sub> O <sub>3</sub>	
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
1893 May 5	B Differences, .	21·45   44·16 + 22·71		8·45   0·0 - 8·45		16·81   16·68 .. ..		0·01   0·0095 .. ..		0·0001   0·00 .. ..		0·00   0·00 .. ..	
" 8	B/5 Differences, .	7·30   21·99 + 14·69		8·46   0·0 - 8·46		16·81   16·78 .. ..		0·002   0·001 - 0·001		0·0001   0·00 - 0·0001		0·00   0·00 .. ..	
" 10	B/10 Differences, .	5·53   13·59 + 8·06		8·46   0·07 - 7·76		16·81   16·62 .. ..		0·001   0·00005 - 0·00095		0·0001   0·0004 + 0·0003		0·00   0·0006 + 0·0006	
" 10	B/15 Differences, .	4·94   10·49 + 5·55		8·46   3·39 - 5·07		16·81   16·63 .. ..		0·00067   0·00 - 0·00067		0·0001   0·00047 + 0·00037		0·00   0·00048 + 0·00048	
" 15	B/20 Differences, .	4·64   8·63 + 3·99		8·46   4·35 - 4·11		16·81   16·62 .. ..		0·0005   0·00 - 0·0005		0·0001   0·0008 + 0·0007		0·00   trace + trace	
" 16	B/40 Differences, .	4·20   6·23 + 2·03		8·46   6·16 - 2·10		16·81   16·60 .. ..		0·00025   0·00 - 0·00025		0·0001   0·0005 + 0·0004		0·00   0·00 .. ..	

REMARKS.—It will be observed that solution B contained practically a similar quantity of organic carbon to solution A (Table VII.), and on comparing the volumes of carbon dioxide formed on complete fermentation of the tartrate in these solutions with those obtained from the tartrate and asparagine in solution A and its dilutions, they will be found approximately equal thereto. (See also p. 613, and Table XVII.)

## SERIES VIII.—COMMENCED 27TH MARCH, 1893.

TABLE XIII.—*Experiments with White of Egg.*

Solution I. contained 0.15 grammes white of egg,  
 0.10 " potassium phosphate, } per litre.  
 0.10 " sodium carbonate,

Date of conclusion of Experiment.	Solution.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>	
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
1894 March 29	I.* Differences,	22.70   + 16.54	39.24**	7.80   - 7.80	0.00	15.68   ..	15.64 ..	0.00   + 0.0026	0.0026	0.00   0.00	0.00	0.0001   - 0.0001	0.00
" 30	I./5† Differences,	7.77   + 5.41	13.18	7.80   - 6.37	1.43	15.68   ..	15.47 ..	0.00   0.00	0.00	0.00   0.00	0.00	0.0001   + 0.0016	0.0017
" 30	I./10† Differences,	5.91   + 3.51	9.42	7.80   - 3.87	3.93	15.68   ..	15.55 ..	0.00   0.00	0.00	0.00   0.00	0.00	0.0001   + 0.0011	0.0012
" 30	I./20† Differences,	4.97   + 1.98	6.95	7.80   - 2.57	5.23	15.68   ..	15.52 ..	0.00   0.00	0.00	0.00   0.00	0.00	0.0001   + 0.0009	0.001
May 2	Tap-water I. Differences,	4.04   + 0.90	4.94	7.80   - 1.07	6.63	15.60   ..	15.50 ..	0.00   0.00	0.00	0.00   0.00	0.00	0.0001   + 0.0007	0.0008
" 3	Tap-water II. Differences,	4.04   + 0.85	4.89	7.80   - 1.02	6.78	15.60   ..	15.50 ..	0.00   0.00	0.00	0.00   0.00	0.00	0.0001   + 0.0007	0.0008

\* Very offensive.

† Quite free from odour.

\*\* The remainder of this solution, immediately after analysis, was mixed with an equal bulk of distilled water. The mixture, after thorough aëration and analysis, was then put into the same bottle as that in which solution I. was kept and preserved in the usual way. After a lengthened period it was again examined, with the following results:—

1895 January 2	Differences,†	20.55   + 2.54	23.09	7.30   - 6.84	0.73	15.60   ..	15.84 ..	0.0014   - 0.0014	0.00	0.00   + 0.00032	0.0032	0.00   + 0.0010	0.0010
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† After the conclusion of this experiment, a considerable quantity of a very thin transparent scale-like deposit was noticed on the sides of the bottle. See also notes to Table XI.

## PART II.

**Experiments with difficultly Fermentable Matters.***Colouring Matters of Peat.*

As an example of difficultly fermentable organic matters, I have employed an extract of fresh peat, collected from a bog which was slightly submerged under running water, and which was situated on one of the Wicklow mountains, and far removed from any source of contamination with animal matters.

The sample of peat was collected on September 15th, 1893.

Two days after, an extract was prepared from it by boiling it in tap-water containing a little sodium hydrate. The extract was filtered into a large glass stoppered jar, which it filled to about two-thirds of its capacity. The extract was then of a deep brown, and it was allowed to ferment until March 8th in the following year, the stopper of the jar being taken off from time to time to renew the air. It was then thoroughly mixed with about five times its bulk of tap-water, and allowed to settle till the following day, when about six litres were decanted off, and the different experiments commenced, which are recorded in Tables XIV and XV.

The results of these experiments were looked forward to with very much interest for several reasons—

First, it was known that peaty-colouring matters in river-waters suffered but little oxidation or other change, unless the waters were subjected to the action of such bodies as clay, when the peaty matters were more or less completely separated by the precipitating action of the clay. There was good reason to believe, however, that the peaty matters in water, when fresh, do undergo at least a slight chemical change. This was evident from the analyses published in the "Sixth Report of the Rivers Pollution Commissioners."\*

These show that the proportion of carbon to nitrogen in unoxidized peaty matter contained in upland surface water is as 11·9 : 1 ; but in peaty matter which has been exposed to oxidation in lakes or large reservoirs, the proportion became 5·9 : 1.

It was quite an open question, however, whether these matters undergo fermentation when present alone, or whether they exert any influence on the fermentation of fermentable matters when present together with such in a water.

\* See also Dr. P. Frankland's Article on Water in "Thorpe's Dictionary of Applied Chemistry," vol. iii., p. 965.

Again, it will be observed that the proportion of carbon to nitrogen in peaty matters is very similar to that of the carbon and nitrogen found in the fermented matters which result from the complete fermentation of sewage during slow filtration through sand. We find from an experiment recorded by Dr. Frankland (Frankland's "Experimental Researches," p.751) that this proportion may be from 9.6 : 1 to 6.3 : 1.

The fermented organic matters which are formed during slow filtration of sewage through such substances as sand or pumice, besides showing a similarly high proportion of carbon to nitrogen, as peaty matter, and we may take it, a similar resistance to fermentation, since it must be remembered these matters are obtained in very decided quantities even after a fermentation in a filter, which has been so complete, that little more than traces of the original ammonia in the sewage may be left unfermented, also possess other properties such as colour and optical properties, which are very similar to those of peaty-colouring matters. Thus, on allowing sewage to percolate very slowly through a pumice filter, I have obtained effluent waters therefrom, coloured very decidedly with a brown tint, which could not be distinguished from the brown varieties of peaty matter, and which on analysis gave the proportion of carbon to nitrogen as 7.1 : 1.

Neither could it be distinguished from peaty water coloured to a similar depth of tint when examined by Professor W. N. Hartley's spectroscopic method. A similar series of dilutions of both afforded identical ultra violet absorption spectra.

The experiments with easily fermentable matters, which have already been quoted, more especially those with the effluent water from the sand filtration recorded in Table V., afford abundant evidence that the organic matters which are formed during the first stage fermentation of animal and vegetable substances may themselves take part in, and suffer a further oxidation during, the subsequent second stage.

The question naturally suggested itself—Do peaty matters undergo similar fermentative changes under similar conditions?

This question appeared the more interesting because from those of my experiments already recorded, and from others, I had come to the conclusion that the presence of small quantities of fermented organic matters, such as peaty-colouring matters, probably are essential to the *nitric* fermentation of *ammonia*, and that the failure to obtain a nitric fermentation of this body under conditions which, as the researches of Professor P. F. Frankland and Mrs. G. C. Frankland, of Warrington and of Winogradsky, have abundantly demonstrated, are most favourable to nitrous fermentation, may be ascribed to the complete absence of peaty or humus-like bodies.

In every experiment which I have made, and in which it has been found that

the oxidation of ammonia to nitric acid has been complete, small quantities of peaty or fermented organic matters have always been present. The same may be said, I think, of the experiments of the above observers in which nitric acid was formed.

In other experiments which I shall have to describe, and in which the only change in the conditions has been a practical absence of all organic matters, I have also obtained abundant nitrous fermentation, but no nitric. In reference to the experiments last mentioned, it is of importance and of interest to note that the organisms present were of the same mixed character as in the case of those experiments in which, as stated, I obtained nitric fermentation.

With these prefatory remarks, I may now proceed to the discussion of the experiments with the extract of peat above mentioned.

The details and results are recorded in the two following Tables :—

[TABLES XIV. AND XV.]



TABLE XV.—*Experiments with Solution of Peat and Ammonium Chloride.*

Solution PA (= P/2 + AmCl.) contained 0.1 grammes ammonium chloride, : : }  
 0.069 " organic carbon, . : } per litre.  
 0.004 " organic nitrogen, . : }

No. of Experiment.	Date of commencement and of conclusion of Experiment.	Description of Experiment.	CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>
1	March 9, 1894, May 12, "	Solution PA = P/2 + Am Cl., Same after fermentation, . . . . Differences, . . . .	59.29 72.26 + 12.97	7.4 0.0 - 7.4	15.14 15.17 —	0.1 0.1 —	0.0 0.0 —	0.0001 0.0 - 0.0001
2	" 14, "	Remainder of PA after fermentation diluted with twice its bulk of distilled water and aerated = PA/3, . . . .						
	June 15, "	Same after fermentation, . . . .	23.80 25.55 + 2.75	7.26 0.0 - 7.26	14.54 14.55 —	0.032 0.028 - 0.004	0.0 0.00225 + 0.00225	0.0 0.0 —
3	" 18, " " 28, "	Differences, . . . . Remainder of PA/3 after fermentation aerated, Same after fermentation, . . . .	22.74 22.18 - 0.56	6.8 0.0 - 6.8	13.58 13.60 —	0.027 0.023 - 0.004	0.0024 0.0024 —	0.0004 0.0037 + 0.0033
4	" 28, " July 17, "	Differences, . . . . Remainder from preceding aerated, . . . .	15.51 16.58 + 1.07	6.5 0.15 - 6.35	12.99 13.09 —	0.002 0.0198 - 0.0022	0.0021 0.00048 - 0.0016	0.004 0.0065 + 0.0025
5	" 21, " Jan. 28, 1895,	Differences, . . . . Remainder from preceding aerated, . . . .	* 5.82 6.58 + 0.77	6.55 0.0 - 6.55	13.19 13.29 —	0.019 0.018 - 0.001	0.0006 0.0032 + 0.0026	0.0070 0.0088 + 0.0018
1a	March 9, 1894, May 14, "	Solution PA diluted with tap-water in the portion of 1 to 9 = PA/10 = P/20 + AmCl., Same after fermentation, . . . .	9.46 21.52 + 12.06	7.5 0.0 - 7.5	15.54 15.55 —	0.01 0.007 - 0.003	0.0 0.0033 + 0.0033	0.0001 0.0 —
2a	" 16, " June 21, "	Differences, . . . . Remainder of PA/10 aerated, . . . .	18.99 19.96 + 0.97	7.24 0.0 - 7.24	14.58 14.48 —	0.007 0.0035 - 0.0035	0.0033 0.006 + 0.0027	0.0 0.0004 + 0.0004
3a	" 22, " Jan. 31, 1895,	Differences, . . . . Remainder from preceding aerated, . . . .	14.83 18.39 + 3.56	7.2 0.0 - 7.2	14.15 13.96 —	0.0024 0.00005 - 0.00239	0.0009† 0.004 + 0.0031	0.0067† 0.00815 + 0.00145
1b	March 9, 1894, May 15, "	Solution PA diluted with tap-water in the portion of 1 to 19 = PA/20 = P/40 + AmCl., Same after fermentation, . . . .	6.69 15.02 + 8.33	7.5 0.0 - 7.5	15.54 15.55 —	0.005 0.0026 - 0.0024	0.0 0.0021 + 0.0003	0.0001 0.0004 + 0.0003
2b	" 17, " June 20, "	Differences, . . . . Remainder of PA/20 aerated, . . . .	11.82 11.06 - 0.76	7.2 0.0 - 7.2	14.37 14.28 —	0.0018 0.0001 - 0.0017	0.0021 0.00018 - 0.00192	0.0004 0.00332 + 0.00292

REMARKS.—\* The very rapid reduction of carbonic acid, here shown during the time the liquid was exposed to the air, was confirmed by a duplicate analysis (5.81). The loss may have occurred by diffusion, but I have not observed so great a loss in any other of my experiments under similar conditions.  
 † These results show that an extremely rapid reduction of nitrous to nitric acid occurred when the liquid was exposed to the air between the 21st and 22nd June. The figures were confirmed by duplicate analyses.

Referring to Table XIV. we find, from the first experiment, that the first stage fermentation of solution P was not complete at the time of commencing the experiments; the remaining portions of solution P were in consequence diluted, as described in the Table, with twice their bulk of distilled water, and exposed to the air for a week to allow of its completion.

From the fact that nitrification had commenced in experiment 2, we may take it that the first-stage fermentation in the solution had been completed. The points most markedly exhibited by experiments 2 and 3 are a formation of carbon dioxide and a loss of oxygen and ammonia. As for the indications of nitrification, they are decided in the former experiment; but the nitric acid formed was equivalent to only about half the quantity of ammonia absorbed, while in the latter experiment no nitric acid appears to have been formed, although a very decided quantity of ammonia was absorbed. It appears then from these experiments that *a fermentation of small quantities of ammonia in the presence of considerable quantities of peaty colouring matters may take place, in such a manner that the ammonia is absorbed, and carbon dioxide is formed, while oxygen is consumed in relatively considerable volumes, but that little or no nitric (no nitrous) acid may be produced.*

In experiment 4 the nitric acid formed is about equivalent to the ammonia absorbed. It is important, however, to note that this last product is the least marked result of the fermentation; the volume of carbon dioxide formed and oxygen consumed being relatively both very much larger in quantity.

Experiments 5 and 6 were made with a diluted portion of solution P/3 prepared for experiment 2, and the former of these two experiments was commenced on the same day as the last mentioned. It is possible and interesting, therefore, to compare the results obtained with the less and more dilute solutions P/3 and P/9.

The first result of fermentation shown with bottle I, on June 12th, less than a month afterwards, was the complete fixation of the ammonia, and the formation of a quantity of nitric acid practically equivalent to the ammonia lost, accompanied by the formation of carbon dioxide.

The results obtained on keeping the other portions of the same solution (in bottles II. and III.) for a further period of about six weeks, were, a further formation of a decided quantity of carbon dioxide and a consumption of oxygen, *but no additional formation of nitric acid.* On re-aërating, however, a portion of the solution in bottle II., remaining from the experiment, and keeping it in two bottles for further periods, one of four, and another of six months, we find a formation of carbon dioxide and a consumption of oxygen, accompanied by a formation of a decided quantity of nitric acid.

The carbon dioxide and nitric acid formed during this last fermentation must have been derived solely from the peaty matters present in the solution. They

therefore confirm the evidence which was afforded by the experiment with tap-water recorded in Tables IX. and XIII., to the effect that the minute quantities of peaty matter in the tap-water underwent a fermentation, though an extremely slow one, into carbon dioxide and nitric acid.

The influence of dilution on the fermentation illustrated by these experiments becomes more decidedly apparent when the oxygen consumed, and the products formed, during the different stages of fermentation represented by experiments 2, 3, and 4, with less dilute solutions, and by experiments 5 (bottle III.), and 6 (bottle V.) are respectively added together and compared. Thus :—

		O <sub>2</sub>	CO <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>
Solution P/3, . .	Exp. 2, 3, and 4, . . . .	− 18·38	+ 14·73	− 0·0012	+ 0·0003
Solution P/9, . .	Exp. 5 (III.) and 6 (V.), . .	− 8·33	+ 6·01	− 0·0004	+ 0·0007

In the less dilute solution P/3, it becomes evident from the above figures that during fermentation a considerable quantity of ammonia was absorbed, and that the quantity of nitric acid formed was, for the period during which the solution was under examination, only about one-fourth that of the ammonia originally present.

On the other hand, in the more dilute solution the reverse action appears to have taken place, since the quantity of nitric acid formed was nearly double that of the ammonia originally present.

Again, the volume of carbon dioxide formed in proportion to that of the oxygen consumed was larger, relatively, in the less than in the more dilute solution.

The fact that peaty matters, when mixed with ammonium chloride, readily undergo fermentation is more clearly demonstrated by the experiments recorded in the next Table XV.

These experiments, it will be noticed, were made with another portion of the same solution of peat, but with this difference, it was mixed with a relatively larger quantity of ammonium chloride. The results then obtained show that a variety of interchanges may occur between peaty matters and ammonia during fermentation.

Thus from experiment 2 we find 7·26 c.cs. oxygen, and 0·004 grammes of ammoniacal nitrogen were taken up, and only 0·00225 grammes of nitrous nitrogen were formed; the volume of oxygen theoretically equivalent to this quantity of nitrous nitrogen being 5·38 c.cs., a volume much less than that actually consumed. From experiment 3 we find the quantities of oxygen and ammoniacal nitrogen taken up are respectively 6·8 c.cs. and 0·004 grammes, and that of nitric nitrogen

formed, 0.0033 grammes; no carbon dioxide was formed during this stage of fermentation, but, on the contrary, 0.56 c.cs. were fixed.

The volume of oxygen theoretically equivalent to the nitric nitrogen formed, viz. 0.0033 grammes is 10.53 c.cs., a volume this time much in excess of that actually consumed. It would seem from the last observation that an interchange between the peaty matters and ammonia took place during this step of the fermentation, but no doubt of a different character, notwithstanding the fact that *carbon dioxide was fixed* rather than formed. It is perhaps right to mention that all the determinations given in this Table, and in the preceeding one, were made with extreme care, all being checked by duplicate analyses, and in the case of many of the nitrogen determinations by triplicate analyses, and further that some of the nitric nitrogen determinations were confirmed by Crum's method with Lunge's nitrometer.

Experiment 4 demonstrates another phase of interchange between the two bodies, and it must be noted of nitrous acid, during fermentation, thus the quantities of oxygen and ammoniacal and nitrous nitrogen taken up were, respectively, 6.35 c. cs., 0.0022 grammes, and 0.0016 grammes, and of carbon dioxide and nitric nitrogen formed, 1.07 cc. and 0.0025 grammes. The volume of oxygen theoretically equivalent to this last-mentioned quantity of nitric nitrogen, supposing part of it was derived from the 0.0016 grammes of nitrous nitrogen taken up and the rest from ammoniacal nitrogen, is 4.15 c.cs., a volume less again than that consumed.

In the last experiment with PA/3, we find a still further phase of interchange during fermentation demonstrated, the quantities of oxygen and ammoniacal nitrogen shown by this experiment as being taken up, and of nitrous and nitric nitrogen formed being, respectively, 6.55 c.cs., 0.001 grammes, 0.77 c.cs., 0.0026 grammes, and 0.0018 grammes. The total quantity of nitrous and nitric nitrogen formed was thus equal to 0.0044 grammes, a quantity largely in excess of the ammoniacal nitrogen taken up. The total volume of oxygen theoretically equivalent to the nitrous and nitric nitrogen formed, assuming that both were derived from the ammoniacal nitrogen, is 11.96 c.cs. There can, therefore, be little doubt from these results that the nitrous and nitric nitrogen formed during this last step of the fermentation, represented by experiment 5, were derived from compounds resulting from the interchanges which, we have seen, must have occurred between the peaty matters and ammonia present in the water during the earlier steps of the fermentation.

It must be remembered in reference to this point, that the organic nitrogen actually present in combination with the peaty matters in the solution PA/3 at the time these experiments were commenced was only 0.00133 grammes. If we sum together the quantities of ammoniacal nitrogen absorbed, and of the

products formed, we see clearly that, although as above shown, the peaty matters played an essential part in the changes which occurred during fermentation, but little carbon dioxide was formed, and that, so far as oxidized products are concerned, the fermentation was practically a nitrogen fermentation. The total figures are:—

O <sub>2</sub>	CO <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>
– 26·96 c.cs.	+ 4·59 c.cs.	– 0·0112 grms.	+ 0·00645 grms.	+ 0·0076 grms.

The total nitrogen oxidized was, as will be seen from these figures, 0·01405 grammes, a quantity decidedly in excess of the ammoniacal nitrogen absorbed.

4·59 c.cs., of carbon dioxide is equivalent to 0·0025 grammes carbon, which is but a small fraction of the total quantity of the organic carbon originally present in solution PA/3, viz. 0·023 grammes.

We have seen that the reverse action to this took place in the solution P/3, which contained but little ammonia relatively to peaty matters. Thus the total volume of carbon dioxide formed was equal to 14·73 c.cs. This volume is equivalent to 0·008 grammes carbon. The oxidised nitrogen, it will be remembered, only amounted to 0·0003 grammes.

One further feature in connection with one of these experiments demands some notice. It is the very sudden diminution of carbon dioxide (shown by the first analysis in experiment 5) which occurred while the solution was kept in a stoppered bottle, only partially filled, from the 17th to the 21st July. No suitable explanation has occurred to my mind to account for this loss. No doubt a portion was due to diffusion into the air-space in the bottle, but with the records of the preceding experiments with the same solution, before one, it is difficult to conceive that the loss was wholly due to this cause. Another source of loss lies doubtless in the possibility of a portion of the gas being fixed by fermentation.

On turning to the experiments with PA/10, we find the influence of dilution shown as markedly as we have already seen it to be in the case of solution P/3 and of the more dilute solution P/9.

Experiment 1*a* shows that the nitrous nitrogen formed was practically equal to the ammoniacal nitrogen absorbed, but that the fermentative products differ essentially in one particular from those obtained simultaneously with nitrification with the less dilute solution, in that a considerable volume of carbon dioxide was formed. But notwithstanding this, the oxygen theoretically equivalent to the nitrous nitrogen = 7·85 c.cs., is slightly in excess of that consumed.

In experiment 2*a* the nitrous and nitric nitrogen together practically equalled the ammoniacal nitrogen lost, but this time, however, a very small volume of carbon dioxide was formed. The volume of oxygen theoretically equivalent to the nitrous and nitric nitrogen formed is 7.70 c.cs., a volume also slightly in excess of that actually consumed, viz. 7.24 c.cs.

It is interesting to note that the fermentation during these two experiments was practically a nitrous fermentation, but that when the solution remaining after the conclusion of the second experiment, was kept in a bottle only partially filled for a single day, the nitrous acid was almost completely fermented to nitric acid.

During fermentation in experiment 3*a*, the nitrous and nitric nitrogen formed, amounting to 0.00355 grammes, was considerably in excess of the ammoniacal nitrogen lost, and a decided quantity, viz. 3.56 c.cs., of carbon dioxide was produced. Nevertheless the oxygen theoretically equivalent to the total nitrous and nitric nitrogen, viz. 8.81 c.cs., is decidedly in excess of that actually consumed, 7.2 c.cs.

On summing together the differences from each experiment, it will be seen that, by the time of the conclusion of the experiment 3*a*, nearly all the fermentable matters, *i.e.* both peat and ammonia, originally present in solution PA/10, must have been fermented, thus:—

O <sub>2</sub>	CO <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>
- 21.94 c.cs.	+ 16.59 c.cs.	- 0.00889 grms.	+ 0.0091 grms.	+ 0.00185 grms.

16.59 c.cs., CO<sub>2</sub> are equivalent to 0.00896 grms. The organic carbon originally present in the solution PA/10 was 0.0089 grms. The exact coincidence between these numbers is probably accidental. Again, the total nitrous and nitric nitrogen amounts, it will be observed, to 0.01095, while the total organic and inorganic nitrogen present in the solution when the experiments were commenced was 0.0107 grammes.

The volume of oxygen theoretically equivalent to the nitrous and nitric nitrogen, assuming that both were derived from the ammoniacal nitrogen, is equal to 27.66 c.cs., which is very much larger than that found by analysis to have been consumed. We may draw the conclusion, then, that the oxygen of the peat itself must have taken part in the fermentative changes.

It is of course, impossible to distinguish any very definite relationship between the figures just considered, owing to the fact that the errors attending them are too appreciable. I merely put them forward here to indicate, which we may

safely take it they do with a fair approximation to the truth, the extent and real nature of the changes which occurred during fermentation in the solution.

The results recorded for the more dilute solution PA/20, in the first experiment 1*b*, are similar in character to those just considered. The volume of carbon dioxide formed, viz. 8.33 c.cs. (equivalent to 0.0045 grammes carbon), shows that the peaty matters must have been nearly completely fermented, as the quantity of carbon present before fermentation was 0.0055 grammes.

It is interesting to note, further, in reference to the results from both the dilute solutions, that the earlier steps of the fermentation which they underwent were almost entirely nitrous.

The second experiment, 2*b*, with the more dilute solution, shows a fixation of carbon dioxide and of ammoniacal or nitrous nitrogen, or both. The oxygen theoretically equivalent to the nitric nitrogen, assuming that it was derived partly from the nitrous nitrogen lost, and the remainder from the ammoniacal nitrogen, is 4.73 c.cs., while the volume actually consumed was 7.2 c.cs.

#### **General Conclusions from Experiments with Solutions of Peaty Matters and Ammonium Compounds.**

On reviewing the evidence afforded by the experiments recorded in Tables XIV. and XV., we may draw the following general conclusions as to the various phases of fermentation which may occur in solutions of peaty matters and ammonium compounds, in the presence of the mixed organisms natural to water, under varying conditions of dilution and relative proportions:—

1. When the proportion of peaty matters present is large, such that the organic carbon amounts to 0.1336 grammes per 1000 c.cs., of solution, and that of ammonium compounds very small (such as 0.0079 grammes nitrogen as ammonia per 1000 c.cs.), a fermentation may occur in which the ammonia is taken up presumably to form new compounds with the peaty matters, since the nitric acid formed is relatively very small, and since also because very decided volumes of carbon dioxide are evolved.

*The volume of oxygen consumed is decidedly in excess of that theoretically equivalent to the oxidised inorganic products formed during the fermentation.*

2. When the same solution is decreased in strength by dilution, which is equivalent to increasing the proportion of oxygen, all other conditions remaining similar (except of course that of mass), the fermentation may take a different course; the volume of carbon dioxide formed becomes decided, and the ammonia becomes

entirely absorbed as before, but the oxidized inorganic nitrogen product is practically exactly equivalent to the ammonia absorbed.

*The oxygen consumed is practically equal to that theoretically equivalent to the inorganic oxidized products formed.*

3. Only nitric acid appears to be formed in the solutions under the stated conditions.

4. When the quantity of peaty matters is not large in proportion to that of the ammonium compounds present in the solution (organic carbon being equal to 0.069 grammes, and ammoniacal nitrogen to 0.1 grammes, per 1000 c.cs.), a fermentation may occur, during the earlier steps of which intermediate combinations between the peaty matters and the ammonia appear to take place, since during such stages the oxidized inorganic nitrogen compounds formed are not equivalent to the inorganic nitrogen taken up, while during a latter stage they are found to suddenly rise in quantity, and finally to become practically equivalent to it. Under these conditions the volume of carbon dioxide formed may be extremely small, relatively to that of oxygen consumed, or to the quantity of nitrogen oxidized.

*The volume of oxygen consumed is, under these circumstances, very much less than that equivalent to the total oxidized inorganic products of the fermentation.*

5. With the conditions stated under 4, we find that the nitrogen fermentation is both nitric and nitrous, the former predominating.

6. When the solution referred to under 4 is diluted, *i.e.* when the proportion of oxygen is increased, the other conditions remaining similar, the course of fermentation appears to be much modified. From the first a large volume of carbon dioxide is formed, and the oxidized inorganic nitrogen is practically equivalent to the ammonia absorbed. When further, the fermentation is pushed to completion, both peaty matters and ammonia appear to undergo nearly complete oxidation to inorganic products.

*The volume of oxygen consumed is, under these conditions, also very much less than that equivalent to the total oxidized inorganic products of the fermentation.*

7. It is interesting to note that the nitrogen fermentation in the dilute solution is both nitric and nitrous, the latter this time predominating, at least in the earlier stages of the fermentation.

For a further conclusion in reference to the subject, see p. 609.

**Relationship between the Oxygen consumed and the Nitrous Acid formed  
during the Fermentation of Ammonia.**

The experiments which have just been considered show that, when the fermentation of ammonia is carried on in the presence of peaty matters, the latter bodies take part in the fermentation, and prevent the true relationship between the oxygen consumed and the ammonia oxidized being seen. With the object of obtaining exact experimental data as to this point, I commenced a further series of experiments with a solution of ammonium chloride in distilled water, to which a little potassium phosphate and sodium carbonate were added, but no organic matter.

Some five litres of this solution were seeded with a few drops of the mixed sediments from the solution of peat (P/9), remaining in bottles II. and III. after the conclusion of experiment 5, recorded in Table XIV. I hoped by this solution to determine accurately the relation between the oxygen consumed and the nitrous acid formed, during a purely nitrous fermentation, carried on in the absence of peaty matters.

At the same time, in order to be able to compare the results of this experiment with those which would follow a fermentation by similar organisms in the presence of peaty matters, I started two further experiments with portions of the same peat solution remaining in the same bottles II. and III. To one portion I added a known quantity of ammonium chloride; to the other a known quantity of potassium nitrite. I had a further object in commencing these experiments, which I will describe later on.

The details and results of these experiments are given in the subjoined Table:—

[TABLE XVI.]

TABLE XVI.—*Experiments to determine the relationship between the Oxygen consumed and Nitrous acid formed during the fermentation of Ammonia.*

No. of Experiment.	Date of commencement and conclusion of Experiment.	Description of Experiment.	CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>	N as NH <sub>3</sub>	N as N <sub>2</sub> O <sub>3</sub>	N as N <sub>2</sub> O <sub>5</sub>
1	July 23, 1894,	Solution in distilled water containing a known quantity of ammonium chloride, and small quantities of potassium phosphate and sodium carbonate, but no added organic matter, seeded with a few drops of the mixed sediments from the solution of peat left in bottles II. and III. after the conclusion of experiment 5, recorded in Table XIV, .	32.96	6.48	12.94	0.0225	0.0	0.0
	Oct. 25, "	Same after fermentation, . . . . .	32.72	0.0	12.91	0.020	0.00224	0.0
1a	" 26, "	Differences, . . . . .	- 0.24	- 6.48	—	- 0.0025	+ 0.00224	—
	" 26, "	Remainder of solution from preceding experiment, aerated, . . . . .	31.52	7.13	14.03	0.019	0.00224	0.0
	Mar. 23, 1895,	Same after fermentation, . . . bottle I.	31.25	0.04	13.87	0.016	0.00464	0.0
	" 26, "	Ditto, . . . . . II.	31.40	0.06	13.95	0.016	0.00472	0.0
	" 26, "	Differences, . . . . . I.	- 0.27	- 7.09	—	- 0.003	+ 0.00240	—
	" 26, "	" . . . . . II.	- 0.12	- 7.07	—	- 0.003	+ 0.00248	—
2	July 24, 1894,	1000 c.cs. of the mixed peat solutions remaining in bottles II. and III. from experiment 5, Table XIV, diluted with 2000 c.cs. distilled water containing a known quantity of ammonium chloride, . . . . .	11.04	6.72	13.19	0.0045	0.0	0.0001
	Nov. 25, "	Same after fermentation, . . . . .	10.92	0.0	13.38	0.0015	0.00016	0.00284
	" 25, "	Differences, . . . . .	- 0.12	- 6.72	—	- 0.003	+ 0.00016	+ 0.00274
3	July 25, "	1000 c.cs. of the same peat solution mixed with 2000 c.cs. of distilled water containing a known quantity of potassium nitrite, . . . . .	11.05	6.72	13.19	0.0	0.0165	0.0025
	Nov. 30, "	Same after fermentation, . . . . .	10.99	0.0	12.98	0.0	0.0016	0.0164
	" 30, "	Differences, . . . . .	- 0.60	- 6.72	—	—	- 0.0149	+ 0.0189

Experiments 1 and 1 *a* show that for the consumption of 6.48, 7.09, and 7.07 c.cs. of oxygen, 0.00224, 0.0024, and 0.00248 grammes of nitrous nitrogen were formed, respectively.

If we raise these volumes each to 10 c.cs., for convenience of comparison, then the quantities of nitrous nitrogen formed would be, respectively, 0.00344, 0.0033, and 0.00351. That is for 10 c.cs. (= 0.1437 grammes) of oxygen consumed, we have, taking the mean of these last three quantities, 0.00342 grammes of nitrous nitrogen formed. In other words, the formation of one part by weight of nitrous nitrogen is accompanied by the consumption of about 4.2 parts by weight of oxygen.

The volume of oxygen theoretically equivalent to the last-mentioned quantity of nitrous nitrogen, viz. 0.00342 grammes, on the assumption that it is derived from ammonia, is 8.14 c.cs.

Thus it will be seen, as was only to be anticipated, that, during the fermentation of ammonia in the absence of all organic matter, the volume of oxygen consumed is in excess of that theoretically equivalent to the nitrous acid formed, in the proportion of 10 : 8.14.

On turning to the result of the experiment with ammonium chloride and peaty matters, the influence of the latter on the former, during fermentation, is shown in a most marked manner. Thus, not only is the quantity of nitrous and nitric acids greater in the presence than in the absence of these substances, but the product of oxidation is almost entirely *nitric acid* and not nitrous acid, as in their absence; the oxygen consumed being much the same in both cases.

If we raise the volume of oxygen, viz. 6.72 to 10 c.cs., for convenience of comparison with the results from experiments 1 and 1 *a*, and the nitrous and nitric nitrogen in the same proportion, we find that for 10 c.cs. of oxygen consumed, 0.00024 grammes nitrous and 0.00408 grammes nitric nitrogen would be formed. These two weights are theoretically equivalent, on the assumption that they were both derived directly from ammonia, to 0.5036 and 13.02 c.cs. of oxygen, respectively.

We see from these figures that, when peaty matters are present with the ammonium compounds, the volume of oxygen consumed during fermentation, instead of being *larger*, is decidedly *less* than that equivalent to the ammoniacal nitrogen oxidized. These results then confirm those recorded in Table XV.

To consider now the determinations of the carbon dioxide. These show that, although the peaty matters must have so largely entered into the chemical changes set up during fermentation in this experiment, *no carbon dioxide was formed*, and it is extremely doubtful whether any was fixed, the difference recorded in the Table being possibly due to experimental errors.

It is possible also, since the ammoniacal nitrogen absorbed during the experiment was slightly in excess of the total nitrogen oxidized, that none of the latter was derived from the peat.

With reference to the question of the source of oxygen, the hydrogen of the ammonia may not have been so completely oxidized to water during the fermentation, in the presence of peaty matters, as in the absence of all organic matter. Some at least of the ammonical hydrogen may have been taken up by the peaty matters, and an increased quantity of oxidized nitrogen would, no doubt, be the results.

But whatever the mechanics of the chemical changes may be, which go on during fermentation, when peaty matters and ammonia are present together, the influence of those matters, one upon the other, cannot be doubted.

I have not hitherto referred to the loss of carbon dioxide shown by the experiments 1 and 1 *a* with the inorganic solution, because, in each case, it is so small as to be scarcely distinguishable from experimental errors. The determinations recorded are important, however, in showing that the carbon fixed must be very small compared with the nitrogen oxidized, and therefore they add additional evidence to that already given by Winogradsky, who showed, by a process of wet combustion, that the assimilation of 1 part of carbon was accompanied by the oxidation of about 35 parts of nitrogen as ammonia to nitrous acid. The mean of the losses of carbon dioxide shown by experiment 1 *a* is 0.15 c.cs., which is equivalent to 0.00008 grammes carbon, the ratio of the mean of the two quantities of nitrous nitrogen, recorded for the same experiment, viz. 0.00244 grammes, is as 1 : 30.5. These figures, it need hardly be said, are simply put forward here as confirmation of those given by Winogradsky.

In some of the preceding experiments, as I have before said, it appears that very definite volumes of carbon dioxide have been fixed, presumably during the formation of organic matters, but in all these experiments either peaty matters or fermented animal organic bodies, or, in the case of these latter, it should perhaps be said, both, as tap-water was employed for them, were present during fermentation.

Thus, the experiment with diluted sewage-water, S<sub>2</sub> recorded on page 588, shows a loss of as much as 0.77 c.cs., with a consumption of 7.6 c.cs. of oxygen, and the formation of only 0.00122 nitric nitrogen, and this experiment was carried out with extreme care, and it may be taken that the errors affecting the determinations are not seriously appreciable, since the quantities determined were small.

*It appears then that peaty matters (and also fermented animal matters) influence the quantity of carbon dioxide which may be fixed during a fermentation of ammonia.*

Referring now to the experiment (3) with potassium nitrite, it will be seen that as in the case of experiment (2) with ammonia and a portion of the same solution of peat, no carbon dioxide was either formed or fixed, so far as analysis could detect. The volume of oxygen theoretically required to oxidize the quantity of nitrous nitrogen which was converted during fermentation to nitric acid, viz. 0.0139 grammes, is 11.12 c.cs., a volume much in excess of that actually consumed (6.72 c.cs.)

It is impossible to suppose that this large excess of oxygen was derived from the quantity of peat present. Possibly intermediate combinations were formed during fermentation between the peaty matters and the nitrous acid, and that part at least of the nitric acid found after fermentation was formed from these combinations.

Unfortunately I have not yet been able to determine the relationship between the oxygen consumed and the nitrous nitrogen oxidized during this fermentation of nitrites in purely inorganic solution, a fermentation which Warrington has shown to be possible, by conclusively proving that nitric organisms develop in solutions containing nitrites and the necessary inorganic salts only.\* Winogradsky, it should be observed, has confirmed this. I trust, however, in a future communication to give the results of some experiments I have already commenced with a view of determining this point, together with the results of a further study on the fermentation of peaty matter and ammonia, upon which I am at present engaged, with the object of completing the work of which the experiments I have given can only be regarded as forming the commencement.

Before concluding my references to the experiments recorded in Table XVI., I should like to draw attention to the results from experiment 2, as compared with those afforded by experiment 1 *a*, and recorded in Table XV. Those of the former experiment show an almost pure nitric fermentation, unaccompanied by either the formation or fixation of carbon dioxide, while those of the latter experiment show that the fermentation was a purely nitrous one, accompanied by the formation of a large volume of carbon dioxide. And yet in both dilute solutions of peat were employed, and each contained a decided excess of ammonia after fermentation. There was, however, one distinct difference between the two solutions. The peat solution employed for the experiment recorded in Table XVI. had undergone several stages of fermentation before being employed for this experiment, while the solution of peat employed for the other was a comparatively fresh one. We may therefore add an additional conclusion to those already drawn, viz. that the changes which peaty matters may undergo in the presence of decided quantities of ammonia, during fermentation may vary with their nature, *i.e.* whether they have themselves undergone fermentation previously or not (see p. 604).

\* Warrington: "Researches on Nitrification, C.S.J., vol. lix., p. 519.

### Nitrification of Pure Urea: An Exception.

As I have shown in the earlier part of this Paper, easily fermentable nitrogenous organic matter, when attacked by water-organisms under continued aërobic conditions, suffer two distinct stages of change, first, the organic carbon is nearly completely oxidized to carbon dioxide, and the organic nitrogen converted into ammonia; second, the ammonia thus formed is oxidized to nitrous or nitric acid.

That urea, when mixed with other organic substances, shows no exception to this rule has been proved by the researches of Warrington and of Munro, and also of other observers; the last-named observer has shown, indeed, that when this substance is mixed only with such a simple body as potassium oxalate,\* the course of fermentation proceeds as above described.

The experiments which I have to describe were, however, made with simple solutions of urea in tap-water, containing in addition only a little sodium carbonate and potassium phosphate.

These experiments were commenced with two objects in view—(1) to ascertain whether nitrogen is evolved during the carbon stage of fermentation of urea, (2) to determine the nature of the nitrogen fermentation, which, it was anticipated, would follow the carbon fermentation.

The experiments were commenced in January, 1893, but the solutions were not examined again until nearly two years afterwards, and I was then surprised to find that even in a comparatively strong solution, containing as much as 0.05 grammes of urea per litre, a quantity of *nitrous nitrogen*, equal to 0.0016 grammes, had been formed, although it was apparently evident from the volume of carbon dioxide formed produced, at the same time, that not more than half the organic carbon originally present in the solution had been converted into that gas. It was feared, at first, that this was due to some leakage which might have occurred between the stopper and neck of the bottle in which the solution was preserved.

Accordingly, another set of experiments with urea was started, but this time with stronger solutions. A similar quantity of nitrous nitrogen was, however, again found, after fermentation, in a solution containing *ten* times the quantity of urea.

It accordingly seemed evident that urea, when *unmixed with other organic substances*, does undergo a change from the very commencement of fermentation, which apparently differs essentially in character from that of other easily fermentable organic substances so far as they are known. In the annexed Table will be found the particulars and results of the experiments above referred to.

\* *Loc. cit.*, p. 640.

## EXPERIMENTS COMMENCED JANUARY 4TH, 1893.

TABLE XVII.—*Experiments with Urea.*

Solution U contained 0.25 grammes urea = 0.05 grammes carbon, and 0.116 nitrogen, }  
 0.10 sodium carbonate,  
 0.10 potassium phosphate, }  
 per litre.

Date of conclusion of Experiment.	Solution.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>	
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
1894 Dec. 29	U/5 Differences, . .	7.45	16.56 + 9.11	8.40	0.0 - 8.40	16.72	16.50 ..	0.0	0.009 + 0.009	0.0	0.0016 + 0.0016	0.0001	0.0002 + 0.0001 ?
" 24	U/15 Differences, . .	4.99	11.92 + 6.93	8.40	0.0 - 8.40	16.72	16.54 ..	0.0	0.005 + 0.005	0.0	0.00288 + 0.00288	0.0001	0.0012 .. ..
" 24	U/20 Differences, . .	4.68	10.29 + 5.61	8.40	0.0 - 8.40	16.72	16.49 ..	0.0	0.003 + 0.003	0.0	0.0014 + 0.0014	0.0001	0.0019 + 0.0018
" 28	U/40 Differences, . .	4.22	7.49 + 3.27	8.40	0.0 - 8.40	16.72	16.51 ..	0.0	trace .. ..	0.0	0.0016 + 0.0016	0.0001	0.0021 + 0.0020

## EXPERIMENTS COMMENCED JANUARY 8TH, 1895.

*Further Experiments with Urea.*

Solution U' contained 0.5 grammes urea = 0.10 grammes carbon, and 0.233 grammes nitrogen, }  
 0.02 sodium carbonate,  
 0.10 potassium phosphate, }  
 per litre.

Date of conclusion of Experiment.	Solution.	CO <sub>2</sub>		O <sub>2</sub>		N <sub>2</sub>		N as NH <sub>3</sub>		N as N <sub>2</sub> O <sub>3</sub>		N as N <sub>2</sub> O <sub>5</sub>	
		I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
1895 Mar. 19	U' Differences, . .	8.06	17.54 + 9.48	8.46	1.75 - 6.71	16.83	16.88 ..	0.0	0.006 + 0.006	0.0	0.0016 + 0.0016	0.0001	0.0002 + 0.0001 ?
" 21	U'/5 Differences, . .	5.74	20.89 + 15.15	8.36	0.0 - 8.36	16.60	16.83 ..	0.0	0.016 + 0.016	0.0	0.00208 + 0.00208	0.0001	0.0002 + 0.0001 ?
" 21	Tap-water, . .	5.11	5.16	8.46	8.44	16.87	16.83	0.0	0.0	0.0	0.0	0.0001	0.0001

We have unmistakable evidence in the above results, especially those afforded by the solutions U' and U'/5, *that nitrous acid is formed in decided quantity simultaneously with ammonia, from the very commencement of the fermentation of urea, under aërobic conditions, and in the presence of the mixed organisms of a natural water.*

The results recorded for the solution U' are particularly instructive, because since a small quantity of dissolved oxygen was found in the solution at the conclusion of the experiment, it may be taken for granted that the fermentation therein proceeded throughout its course, so far as it went, under aërobic conditions.

Under these conditions we find that the nitrous nitrogen formed was practically one-fourth the quantity of ammoniacal nitrogen produced at the same time, the former amounting to 0.0016 grammes, and the latter to 0.006 grammes.

The volume of carbon dioxide, viz. 9.48 c.cs., equal to 0.005 grammes carbon, which was simultaneously formed with these quantities of nitrous and ammoniacal nitrogen, is not in atomic proportion therewith, but is equivalent, it will be found, to a quantity of carbon much greater than such proportion would allow. It must, therefore, have been derived, in part at least, from some intermolecular changes set up in the portion of the urea fermented. If the composition of these bodies, or body, were known, we should then have, with the results recorded in the above Table, all the factors required for the precise formulation of the changes which urea undergoes during fermentation under the conditions given.

The study of this fermentation of pure urea by the method here employed became, in fact, of very great interest. To what, for instance, is this formation of the nitrous acid during the first-stage fermentation of urea analogous?

Is it analogous to the formation of the same body during true nitrification? I am inclined to think not. It is rather, I should say, to be classed with the oxidized organic bodies which we know are formed during the first-stage fermentation of more highly carbonated compounds, the nitrogen in the said nitrous acid substituting carbon, and this being possibly owing to the very small quantity of carbon contained in the urea, and to the chemical characters thereof. Before, however, this and other points suggested by the above experiments can be decided, a much more extended investigation will be necessary, and this, I hope, to commence shortly.

The fermentation in the solution U'/5 appears from the results recorded for it, to have proceeded further than in the solution just considered. A larger volume of oxygen was consumed, and a relatively larger quantity of nitrous nitrogen was formed. The carbon dioxide and ammonia were also increased, and in such large proportion that an anaërobic fermentation must, no doubt, have partially set in during the experiment.

### Nitric Fermentation in Solution of Urea.

Turning once more to the results recorded in Table XVII., we notice that those afforded by the more dilute solutions U/20 and U/40 show that decided quantities of nitric acid were formed, but that apparently the nitrous acid first produced did not suffer further oxidation. This nitric fermentation may, however, have been brought about by the peaty matters in the tap-water employed for making up the solutions, and it is possible that *nitric* fermentation would not have set in in their absence. This is a question, however, which I must leave to a further communication.

### Similar Quantities of Carbon Dioxide formed by Fermentation in Solutions containing similar Atomic Proportions of Carbon, as Urea, and as Potassium Sodium Carbonate.

It is interesting to compare the results with the above two dilute solutions of U, with those obtained from the dilutions IV/40 and IV/80 of the solution of potassium sodium tartrate employed for the experiments recorded in Table XI. These two sets of solutions contained similar quantities of carbon, the one as urea, and the other as tartrate. From the long time during which the solutions were kept, it may be taken that the peaty matter in the tap-water with which they were made up suffered fermentation as well as the added substances. It is interesting to observe, therefore, that the volumes of carbon dioxide in each set are similar one to the other. (See also Tables VII. and XII.)

It will also be noticed that in both sets the conversion into oxidized inorganic products of the fermentable substances originally present in the solutions, must have been nearly quantitatively complete.

### The Theory of Nitrification.

It seems to have been established from the researches of a number of observers, more especially from those of Mr. Warrington, Professor P. F. Frankland and Mrs. G. Frankland, Dr. Munro, and M. Winogradsky, that the nitrification effected by soil organisms is brought about by two species, one of which oxidizes ammonia to nitrates, while the other oxidize nitrites to nitrates.

These observers found that it was easy to obtain a nitrous fermentation in solutions of ammonia containing certain inorganic salts, but practically no organic matter, by means of organisms cultivated from soil. The attempt, however, to

obtain a nitric fermentation of ammonia under like conditions has, so far as I know, failed.

It was, however, perfectly well known that a nitric fermentation could be set up in inorganic solutions of ammonia, seeded by fresh soil. The question remained in obscurity until Warrington, in his last published "*Researches on Nitrification*," already referred to, showed that he had, in the course of his work, obtained some mixed organisms, some of which at least produced neither nitrous nor nitric acid from ammonia, but which energetically converted nitrites into nitrates.

Warrington showed further, that the presence of ammonia retarded the action of the nitric organisms on nitrites.

Winogradsky has since isolated, from soil cultivations, the organisms which has the power of fermenting nitrites to nitrates in inorganic solutions.

On referring to the experiments, which I have recorded on the fermentation of ammonia in the presence of peaty matters, and also, indeed, to such of those of other observers as were carried out in the presence of fresh soil, which it must be remembered no doubt contained organic bodies of a similar character and influence, in the shape of humus, to the peaty matters of my experiments, one cannot but be struck with the apparently direct influence of these matters on the fermentation. Thus, in the experiments 2, 3, 4, and 5, recorded in Table XV., the solution employed for which contained a large quantity of ammonia chloride relatively to the peaty matters, but in which the peaty matters were present in decided quantities, the nitric fermentation predominated, notwithstanding the fact that a considerable quantity of ammonia remained after the last experiment, No. 5; while with the more dilute solution in which the ammonia, so far as the fermentation was concerned, still remained large in quantity, but in which the peaty matters might be considered small in their relation to that of the ammonia, we get the reverse action shown, and the nitrous fermentation is seen to have predominated.

Again, if we refer to the experiments recorded in Table XVI., we find three solutions, all seeded with similar organisms, but differing markedly in other essential conditions:—

No. 1 is a purely inorganic solution, and in it a purely nitrous fermentation took place.

No. 2 contained peaty matters, and in it not only was a nearly pure nitric fermentation obtained, but the oxidized inorganic nitrogen product, in proportion to the oxygen consumed, was decidedly larger than in the case of solution 1.

Again, in solution No. 3, a nitric fermentation of nitrous acid is shown, in which the oxidized nitrogen product is, as in the case of the solution No. 2, theoretically equivalent to a much larger volume of oxygen than that actually consumed.

Here then, with the common condition of similar organism established in each solution, we get, in the absence of peaty matters, nitrous fermentation of ammonia, while in their presence we get a nitric fermentation of either ammonia or of nitrous acid.

The question therefore suggests itself—do not these peaty matters, when present in a water, exercise a dominating influence on the course of the fermentation of ammonia, and determine the nitric fermentation which is so noticeable concurrently with their presence?

I would go further and venture to suggest, that the explanation of the observed fact—that the nitrification of ammonia in a mass of aërated soil results normally in the production of nitrates only (Warrington)—is to be referred to the presence of organic substances in the soil, viz. humus, allied in character to the peaty matters of natural waters.

If this explanation be accepted, the question of nitrification would appear to stand thus:—

1. The nitrous organisms of soil thrive in inorganic solutions containing ammonia.

2. The nitric organisms of soil are gradually killed, or lose their vitality, in inorganic solutions containing ammonia.

3. The nitric organisms of soil thrive in inorganic solutions containing nitrites.

4. The nitrous organisms cannot oxidize nitrites to nitrates in inorganic solutions.

5. The presence of peaty or humus matters appears to preserve the vitality of nitric organisms during the fermentation of ammonia, and establishes conditions whereby it is possible for the nitric organisms to thrive simultaneously in the same solution with the nitrous organisms.

6. Query—Is it possible for either the nitrous, or nitric, or other organisms to separately set up the complete oxidation of ammonia to nitric acid, in the presence of peaty or humus matters?

## PART III.

**Bearing of the foregoing Experiments on the Analysis of Potable and Polluted Waters.**

Up to the present time the bacteriological methods which have been proposed for the examination of waters have not resulted in bringing any very great practical assistance to bear on the subject of the technical examination of pure and polluted waters. I except, of course, those most important ones which can be employed for demonstrating the presence or absence of pathogenic organisms in a water. The suggestion that the number of microbes present in a given volume of water would give a useful indication or otherwise of its purity, from which so much was at first expected, has been shown, more especially in this country by the researches of Dr. P. F. Frankland,\* to be of little practical value, except when applied for the examination of the efficiency of filtration, since many bacteria are capable of enormous and extraordinarily rapid multiplication even in waters of very high organic purity.†

Bacteriological research has been instrumental rather, as I observed in the introduction to this Paper, in demonstrating the true agencies at work in setting up processes of oxidation in waters, and in thereby indicating new lines of research for completing our knowledge of the chemistry of natural and polluted waters.

The experiments which have been described in this Paper, may, I venture to hope, prove a step onward in this direction, since they clear up, on the one hand, certain points in reference to the analysis of potable waters which have hitherto been more or less obscure; and, on the other hand, they indicate a satisfactory method for the examination and analysis of polluted waters.

First, as regards the examination of potable waters, these experiments show conclusively that (1) the absence of easily fermentable matters of all kinds, and (2) the indication that the water has been subjected to efficient artificial or natural filtration, are two conditions, positive evidence of which it is of the first importance to seek for in all waters to be used for dietetic purposes.

Broadly speaking the first condition will have been established if the water contains no free ammonia, or only small traces of this substance, since of the easily fermentable substances found in waters it is the last to be fermented.

The second condition will, no doubt, have been established, if, in addition to the absence of free ammonia, traces only of organic matter (fermented) are found in the water.

\* "Proc. Roy. Soc.," 1886, p. 526.

† Article by Dr. P. F. Frankland, on "Water," already referred to, p. 990; see, also, work on "Micro-organisms in Water," by Dr. and Mrs. P. F. Frankland.

In reference to this point it must be remembered that during efficient filtration all but traces of peaty or humus matters are separated. Hence, the absence of all but traces of these matters and of ammonia may be accepted as one proof of efficient filtration in water.

That efficient filtration of all water to be used for dietetic purposes is a prudent precaution in the interests of health must be accepted from the property which bacteriologists have shown properly constructed filters to possess, of separating pathogenic organisms from water (Koch on Cholera, 1894).

It will be observed that the above two conditions in first-class potable water may be ascertained by the methods in ordinary use for water analysis.

In cases of doubt or suspicion, however, a careful examination of the character of the organic matters present should be made.

There can, I think, be no question that the method I have employed is capable of revealing both the nature and amount of polluting matters, should they be present in a water, or of proving their absence if not present. I can state from my own experience that examinations of such suspicious waters have afforded me results which have left no doubt in my mind as to their suitability or otherwise for dietetic purposes.

When we turn to the consideration of polluted waters, the matter assumes an entirely different aspect, for it is quite evident from the experiments which I have described, that the methods of analysis of potable waters, when applied to that of polluted waters, are not only quite incapable of indicating the true character of the polluting matters, but that they may even lead to absolutely misleading results.

From the experiments with polluted waters which I have recorded, it may be gathered that it is essential, in order to predict the action which a given volume of a particular polluted water will exert, when discharged into a watercourse of known volume and flow, to determine beforehand the exact volume of atmospheric oxygen which will be required for the complete fermentation of the polluting matters present, and that it is necessary also for technical purposes to approximately determine what fraction of that volume of oxygen is required for the first stage of fermentation of these matters. Under no circumstances ought a polluted water be discharged into a watercourse in such volumes that the dissolved oxygen in the mixture of the two waters, pure and polluted, is not more than sufficient to supply that required for the first-stage fermentation of the polluting matters.

This I consider is necessary, because the first stage of fermentation of easily fermentable organic matters proceeds much more rapidly in a water exposed to the atmosphere than does the solution and diffusion of atmospheric oxygen through the water. Hence, if the quantity of dissolved oxygen of a water is insufficient for the needs of this stage of fermentation of any polluting matters in it, putrefactive fermentation will set in.

It is otherwise with the second-stage fermentation of a polluted water, since this stage of fermentation probably does not proceed so rapidly in a water exposed to the same conditions as the diffusion of atmospheric oxygen into it, and since, if it does, secondary products of a poisonous nature, such as are formed during putrefaction, cannot be simultaneously formed with nitrous or nitric acid from the very nature of the process of nitrification.

It is right, therefore, in dealing with the question of the pollution of a water-course, to make this distinction between the oxygen required for the first stage fermentation and that required for the second stage.

I have made these remarks more particularly with the view of drawing attention to the possibility which the method of observation I have employed in this investigation presents, of formulating definite standards of impurity which should be allowed in the case of drainage waters discharged into a watercourse; it being possible, it should be observed, to formulate a standard according to local conditions and requirements.

A simple standard, which Local and River Conservancy Boards could control, could be framed as follows:—

The limit of impurity to be allowed to a given water to be such, that, when a given volume of it is mixed with a given volume of tap- or other good water, and the mixture kept in a bottle out of contact with air, under the conditions I have described, for a sufficient length of time, a decided oxidation of the ammonia originally present in the mixture into nitrous, or nitric, acid shall be indicated.

This is, however, merely a suggestion. Were the principle of the proposed standards adopted, experience would show how best to formulate them.

### General Conclusions.

The following conclusions may be drawn from the experiments recorded in this Paper:—

1. That the method and apparatus described in the Paper for preserving natural waters, or artificial solutions, out of contact with air, and for analysing the gases in solution in them, before and after keeping, are capable of yielding very accurate results, and that the method is not attended with any great experimental difficulties.

2. That observations of the changes in composition of the gases in solution, which take place during the course of fermentation in the presence of mixed organisms, under the conditions described, when made in conjunction with an examination of the changes which simultaneously occur in the organic and inorganic nitrogenous bodies in the water, are productive of extremely important results, and are necessary if it be desired to investigate completely the chemical changes which accompany such fermentations.

3. That with the aid of such observations it is possible to study the various chemical changes which take place progressively during the fermentation within certain well-defined conditions of any fermentable substance or substances, from commencement to completion, at any intermediate step desired.

4. That it hence becomes possible to demonstrate that the fermentation of substances under aërobic conditions by the organisms usually present in water, takes place progressively in two distinct stages: (1) that in which the organic substances are completely broken down, the carbon and nitrogen being largely converted into carbon dioxide and ammonia, a little organic matter remaining as such, but in an altered form; and (2) that in which ammonia is oxidized to nitrous or nitric acids, or both.

5. That the first stage of fermentation must be complete before the second stage can set in.

6. That the *organic* substances which result as products of the first stage of fermentation, may undergo further change during the subsequent stage, and give rise to the formation of carbon dioxide, and possibly also to nitric acid.

7. That peaty matters when present alone in a water undergo very slow change, but when present with ammonium compounds, they readily undergo fermentation together with the ammonium compounds, just as the organic matters, which, as above stated, are formed during the first stage of fermentation of animal, vegetable, or artificial organic substances, do during the after-fermentation of ammonium compounds which may have been also formed thereby, or which may have been previously present or added.

8. That the presence of the above-mentioned fermented organic matters, or peaty matters, appear to determine the *nitric* fermentation of *ammonia*, since in their complete absence, similar organisms being present, only nitrous acid is obtained.

9. That during the intermediate stages of a fermentation of mixed peaty matters and ammonium compounds, various interchanges between the two appear to take place, the character and extent of which apparently depend upon the relative quantities of peaty matters, ammonia, and dissolved oxygen present, and also upon the character of the peaty matters themselves, whether they have been freshly formed, or have undergone any previous fermentative changes.

10. That in the presence of small quantities of peaty, or other fermented organic matters, carbon dioxide and ammonia may become "fixed," during fermentation in appreciable quantities, no doubt from Winogradsky's researches to form organic matter.

11. That the formation of one part by weight of nitrous nitrogen during the fermentation of ammonia, in the complete absence of organic matter, is attended by the consumption of about 4.2 parts by weight of oxygen.

12. That for similar volumes of oxygen consumed, the quantity of nitrogen oxidized during the fermentation of ammonia is distinctly greater, in the presence of peaty or other fermented organic matters, than in their absence.

13. That for similar volumes of dissolved atmospheric oxygen consumed, the quantities of carbon dioxide and ammonia "fixed" are also more appreciable in the presence of those organic matters during fermentation, than in their absence.

14. That from the earliest stages of an aërobic fermentation of a strong solution of pure urea, containing no other easily fermentable organic substances, *nitrous* nitrogen is formed in addition to ammoniacal nitrogen, in the proportion of about 1 : 4. It is possible that the chemical changes which here result in the formation of nitrous acid are not analogous to those attending the formation of nitrous acid in the fermentation of ammonia, but rather to those attending the formation of the oxidized organic matter during a first-stage fermentation, the nitrogen, in the case of urea, taking the place of the carbon in a more highly carbonated organic compound.

15. That by determining the changes in the dissolved gases, and in the organic and inorganic nitrogenous compounds, which accompany fermentation in natural and polluted waters, it is possible not only to differentiate easily fermentable from difficultly fermentable substances present, but to approximately estimate their quantity.

16. That such determinations are of very great value in the case of polluted waters, because in addition to affording very accurate estimations of the total quantities of fermentable matters in them, in terms of the exact volume of atmospheric oxygen necessary for their complete fermentation, it is possible by proper examination to determine what fraction of such volume is required for the first stage of fermentation, and what fraction for the second—distinctions of the utmost importance in considering the technical aspect of the pollution of rivers.

17. That in the course of the first-stage fermentation of some sewage-waters, there is some evidence to show that appreciable quantities of atmospheric nitrogen may be fixed.

Before concluding this portion of my study, it is due to my friend, Mr. James Carson, Assoc. R.C.Sc.I., to acknowledge the most valuable services which he has rendered me during the whole time I have been engaged upon this investigation. He has not only assisted me throughout in carrying out the very laborious analytical determinations incidental to the work, but has further assisted me by making and perfecting the mechanical arrangements of the beautiful model of my gas-analysis apparatus, which is described in this Paper.



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(PLATES L TO LXVIII.)

COMMUNICATED BY PROFESSOR HADDON.

[Read JANUARY 23, 1895.]

IN the first part of this Monograph\* we described the species belonging to the Section *Podocopa*, to which belong the well-known genera *Cypris*, *Cythere*, and their allies, familiar to every microscopist who has dipped net into pond or sea. The sections of which we now treat are entirely marine in habit, and are for the most part scarce and difficult to obtain, being rarely or never found—in northern latitudes at any rate—except in the depths of the sea or swimming at some distance from the shore.

Of the species now described, the following are here recorded from the British seas:—

SECTION II.—*Myodocopa*.

<i>Asterope Mariæ</i> , Baird.	<i>Philomedes Mac Andrei</i> , Baird.
„ <i>teres</i> , Norman.	<i>Nematohamma obliqua</i> , Brady and Norman.
„ <i>elliptica</i> , Phillipi.	<i>Sarsiella capsula</i> , Norman.
<i>Crossophorus imperator</i> , G. S. Brady.	<i>Conchæcia elegans</i> , G. O. Sars.
<i>Cypridina norvegica</i> , Baird.	„ <i>Haddoni</i> , Brady and Norman.
<i>Philomedes brenda</i> , Baird.	<i>Conchæcilla daphnoides</i> , Claus.
„ <i>interpuncta</i> , Baird.	

\* “Trans. Roy. Dub. Soc.,” vol. iv., 1889, pp. 63–270, Pl. VIII.—XXIII.

SECTION III.—*Cladocopa*.*Polycope orbicularis*, G. O. Sars.*Polycope dentata*, G. S. Brady.,, *punctata*, G. O. Sars.*Polycopsis compressa*, Brady and Robertson.SECTION IV.—*Platycopa*.*Cytherella abyssorum*, G. O. Sars.*Cytherella lævis*, G. S. Brady.

We indicated our views in the first part of this Monograph, that for zoological purposes the North Atlantic should be considered as defined southwards by lat. 35° N., beyond which we would style the Ocean the Tropical Atlantic; but having received from the Marquis de Folin a number of abyssal forms taken by the French Government expeditions, in the "Travailleur" and the "Talisman," off the coast of Morocco, we have thought it advisable to include these species, inasmuch as living in very deep water at or near freezing point, it was probable that they would hereafter be found in the bed of the Atlantic further north. The species thus obtained consist of many most interesting forms which have been picked out by the Marquis from the dredged material of these expeditions, and for enabling us to describe the species we are deeply indebted to him. We have also included here the Mediterranean species, which were excluded from the *Podocopa* as being so numerous.

To Professor G. O. Sars we owe our sincere thanks for some Norwegian species. To Dr. John Murray we are indebted for some *Conchæiidae* procured in the tow-net during the "Triton" Expedition in 1882, including the remarkable *Conchæilla lacerta*. Mr. T. Scott and Mr. D. J. Scourfield we have to thank for their kindness in supplying us with specimens of some *Podocopa*, which are described in the Appendix.

To Professor Haddon we are indebted for a tow-net gathering from 220 fathoms taken 40 miles N. N. W. of Achill Head on the west coast of Ireland, which contained some very interesting *Conchæiidae*.

In the Appendix just referred to will be found additional notes respecting the nomenclature &c., of certain forms contained in the former portion of this Monograph, as well as descriptions of new species since added to the fauna of N. W. Europe.

In consequence of the small size of *Ostracoda* it is extremely difficult to procure spirit-preserved specimens from the deep sea, and although the *Myodocopa*, being much larger than the *Podocopa*, would be detected by the experienced eye of a Carcinologist who had studied them, yet the Zoologists usually attached to

Government Expeditions cannot be expected thus to notice them. Hence it is that in a large number of cases the only examples which have come into our hands are such as have been picked out of dried material.

It struck us that, notwithstanding their dried condition, it might yet be possible by maceration to get some idea of the withered inmates of the shells. We therefore made experiments, and succeeded in restoring the animals beyond our most ardent expectations. All the portions of the animals figured in the genera *Streptoleberis*, *Tetragonodon*, *Paramekodon*, *Rutiderma*, also of the species *Asterope elliptica* and *teres* ( $\sigma$ ), as well as in a great measure of *Cytherella*, have been taken from dissections of animals which have been preserved in a dried state for very many—in one case as long as twenty-three—years, and we are satisfied that these drawings will be found to be almost as exact, so far as they go, as those taken from spirit-preserved examples, though, no doubt, a seta or spine here and there, or other minute character, will be inexact, or not represented.

It was not until our Monograph was nearly completed, and on the point of going to press, that there appeared the splendid work of Herr. G. W. Müller on the Ostracoda of the Gulf of Naples. This work has, in the case of some few species, anticipated our descriptions, and we have, as far as possible, rectified our nomenclature in conformity with it. For the rest we have thought it best to let our MS. go to press as it was originally written.

The species belonging to this section described from the Mediterranean by Müller, but not noted by us, are the following:—

<i>Cypridina squamosa</i> ,	G. W. Müller.	<i>Polycope tuberosa</i> ,	G. W. Müller.
<i>Philomedes aspera</i> ,	„	„ <i>maculata</i> ,	„
„ <i>lævis</i> ,	„	„ <i>reticulata</i> ,	„
<i>Pseudophilomedes angulata</i> ,	„	„ <i>frequens</i> ,	„
<i>Sarsiella lævis</i> ,	„	„ <i>striata</i> ,	„
<i>Cylindroleberis Lobianci</i> ,	„	„ <i>fragilis</i> ,	„
<i>Archiconchæcia striata</i> ,	„	„ <i>dispar</i> ,	„
<i>Conchæcia procera</i> ,	„	<i>Polycopsis serrata</i> ,	„
„ <i>rotundata</i> ,	„	<i>Cytherella sordida</i> ,	„
<i>Polycope rostrata</i> ,	„		

As an introduction to this part of the Monograph we here give a synopsis of some distinguishing characters of the sections and families. For fuller account of the families of the *Podocopa* we would refer to pp. 65–67 of the first part of this Monograph.

## OSTRACODA, Latreille, 1802.

## SYNOPSIS OF SECTIONS AND FAMILIES.

## SECTION I.—Podocopa, G. O. Sars, 1865.

Antennæ simple, sub-pediform, geniculate, furnished with ungues, in other respects not very unlike the antennules. Both antennules and antennæ either bear long setæ, being thus adapted for swimming, or are shortly setose, when the only means of progression is walking. First maxillæ always furnished with a branchial appendage. Caudal laminæ either rudimentary, or when developed consisting of slender, elongated laminæ, with few terminal ungues.

- A. Last three limbs pediform, without branchial appendage. Mandible simple, very narrow and stiliform (without palp or branchial appendage), enclosed in a tube formed by the labrum and labium, the whole apparatus adapted for suction. Caudal laminæ rudimentary. Fam. *Paradoxostomatidæ*, Brady and Norman, 1889.
- B. Last three limbs pediform, without branchial appendage. Mandible toothed and adapted for chewing, furnished with a sub-pediform palp and a branchial appendage. Caudal laminæ rudimentary, in the form of setiferous lobes. Fam. *Cytheridæ*, Baird, 1850.
- C. Last three limbs pediform, the first with a branchial appendage. Mandible nearly as in *Cytheridæ*. Caudal laminæ not developed, represented by a small sub-conical process. Fam. *Darwinulidæ*, Brady and Norman, 1889.
- D. Last three limbs pediform, the first of these with a branchial appendage. Mandible nearly as in the *Cytheridæ*. Caudal laminæ not large, narrow, linear, furnished with terminal ungues as in *Cyprididæ*. Fam. *Bairdiidæ*, G. O. Sars, 1887.
- E. Only last two limbs pediform; the preceding pair small and maxilliform in female, larger and modified for grasping in male; furnished with a branchial appendage. Mandible nearly as in *Cytheridæ*. Caudal laminæ long, narrow, linear, terminating in ungues. Fam. *Cyprididæ*, Baird, 1850.
- F. As *Cyprididæ*, but the caudal appendages minute, consisting of setiform processes, which run out to a very fine extremity. Fam. *Cypridopsidæ*, Brady and Norman.

SECTION II.—*Myodocopa*.

Antennæ two-branched; basal joint very massive and large, subcordate or pyriform; larger branch natatory, its first joint long, naked, followed by many short setiferous joints; secondary branch usually minute, sometimes absent, in male generally rather larger, and formed for grasping. Antennules scarcely natatory, except in males. Mandibular palp very large, geniculate; subpediform, destitute of branchial appendage. First maxillæ without branchial appendage. Caudal laminæ broad, flattened, hinder margin beset with unguis.

\* All limbs posterior to the first maxillæ pediform or subpediform.

Last limb minute, consisting of two articulations. No eyes or ocellus.

Antennules short, in ♀ weak, indistinctly articulated, immoveable; in ♂ larger, articulated, with long terminal setæ. Mandibles with well developed teeth. Small vibratory laminæ attached to penultimate and antepenultimate pediform limbs. Caudal laminæ broader than long. Fam. *Conchæciidæ*, G. O. Sars.

\*\* Limbs posterior to the first maxillæ not pediform or subpediform; last limb in the form of an elongated, flexible, annulated, vermiform organ of great length, curved upwards and backwards, ending in two lips, and furnished at and near the extremity with long, delicate spines, which are barbately spinulose at their apices. Antennules large, 5-7 jointed, geniculated at the end of first joint, with long setæ at the extremity. Mandibles without teeth. Eyes generally present and compound, pedunculated, widely separated, and also between them a simple eye. Large vibratory laminæ attached to the antepenultimate, and usually also to the penultimate limbs. Caudal laminæ oval or subtriangular, longer than broad. Ova carried within the shell behind the body.

1. Antennules having a terminal unguis as well as setæ. Mandible with a recurved, falciform, toothed process. First maxillæ consisting of only two lobes, one elongated, triangular, naked; the other thin, membranous, falcate, ending in two setæ, and having the inner edge closely set with pectinately arranged, very long setæ. Second maxillæ consisting of a single, flattened, unjointed member, curiously twisted in the middle, its inner margin edged with setæ; vibratory lamina large. Third maxillæ simple, subtriangular; distal edge setose; no vibratory lamina. Animal furnished at the back of the hinder portion of the body with two series of membranous, lamelliform branchiæ. Fam. *Asteropidæ*, Brady and Norman.

2. Antennules without a terminal unguis. Mandible with or without a small simple or bifid hirsute process near the base; the palp ending in unguis. First maxillæ many-lobed, and furnished with a subpediform 2-3 jointed palp. Second maxillæ minutely-lobed, the last lobe generally furnished with distinct teeth; a small unjointed, sometimes three-lobed, palp. Third postoral appendages also maxilliform. No branchiæ.

A. Shell with a deep sinus in front for the protrusion of the antennæ; anterior extremity projected in rostrate or subrostrate form. Mandible palp ending in unguis. Teeth of second maxillæ varying in form in different genera. Fam. *Cypridinidæ*, Baird, 1850.

B. Shell oval, truncate behind, antennal sinus very shallow, a mere sinuation of the margin; surface of valves rugose. Antennules (♀) without sensory organ. Antennæ without any secondary branch. Mandible—palp with last joint of great size, ending in a distinct and large chela. Second maxillæ furnished with tooth. Fam. *Rutidermatidæ*, Brady and Norman.

C. Shell oval or round, no antennal sinus. Last three joints of mandible—palp very short, without setæ, each furnished with a well-developed unguis. Second maxillæ without teeth. Fam. *Sarsiellidæ*, Brady and Norman.

### SECTION III.—*Cladocopa*, G. O. Sars, 1865.

Antennæ two-branched, both branches well developed, moveable and natatory. Antennules also natatory, not geniculate, ending in long setæ. Mandibles distinctly toothed, with two-jointed palp, the first of which carries a small branchial appendage. Only two pair of appendages posterior to the mandible, the first bifid and natatory, the second membranaceous and branchial. No eyes. Caudal laminæ short, their posterior margin spinose and unguiferous. Fam. *Polycopidæ*, G. O. Sars, 1865.

### SECTION IV.—*Platycopa*, G. O. Sars, 1865.

Antennæ two-branched, flattened, resembling the feet of Copepoda; basal portion biarticulate and geniculate; branches flattened, composed of few joints, and bearing many setæ on both margins. Antennules very large and strong,

many-jointed, geniculated at the base, shortly spiniferous. Mandibles small and weak, palp large. Three pair of limbs posterior to the mandibles, all maxilliform. Palp of the mandibles and first maxillæ bearing internally a comb of large setæ. First and second maxillæ furnished with a large vibratory lamina. Third pair rudimentary in the female, in the male well developed and prehensile. Caudal laminæ small and narrow, spiniferous at the extremity. Fam. *Cytherellidæ*, G. O. Sars, 1865.

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## SECTION II.—*Myodocopa*.

Shell ovate, elongated-ovate, or round, sometimes truncate behind, and often produced to less or greater length at the infero-posteal corner, or sometimes at the supero-posteal corner. On the lower portion of the front margin there is usually a sinus for the protrusion of the antennæ, and above this the shell is projected in more or less rostrate form. Valves highly calcareous, or thin and almost membranaceous; surface smooth and polished, or hispid, sometimes reticulated; at others pitted or roughly sculptured.

Eyes, usually two, pedunculated, or rudimentary, or even absent in some cases: a central ocellus, except in *Conchæciadæ*. Always a frontal tentacle of greater or less length, simple except in *Conchæciadæ*, where it is more developed, and usually has an expanded, distal, articulated process (capitulum).

Antennules not adapted for swimming, generally with sensory appendages, which are variously modified, for the most part of considerable size, but small in *Conchæciadæ*. Antennæ always consisting of an immensely strong, muscular, pyriform or subcordiform basal joint, and a multiarticulate branch, the basal joint of which is long, the rest short, and all, except the first joint, furnished with long annulated setæ, which always in ♀, and usually in ♂, are plumose, and form a powerful swimming organ: a secondary branch—usually, but not always, present in ♀—when present minute; in ♂ more developed, and usually (not in *Cypridina*) formed for grasping, the last of the two or three joints folding back upon the preceding.

The labrum and labium are little developed; largest in the *Conchæciadæ*. In *Conchæciadæ* only is the mandible provided with teeth, but is often furnished with a simple or bifid hirsute, or a reflexed falcate process in their place. Attached to the mandible is a 3–4 jointed palp, the first joint of which, in genera provided with the hirsute or falcate process just referred to, is furnished with some peculiarly modified spines: the palp usually ends in one or more ungues, but in *Rutiderma* a strongly-developed chela takes their place.

The first maxillæ are furnished with several lobes and a two-jointed palp, the terminal joint incurved, and terminating in spines or ungues. Second and third maxillæ in *Asteropidæ* are in the form of very simple, seta-edged laminæ; in *Cypridinidæ*, *Rutidermatidæ*, and *Sarsiellidæ*, maxilliform, consisting of one or several lobes, and behind furnished with thin, seta-surrounded vibratory laminæ. In *Conchæciadæ* these limbs are still small, but many-jointed, pediform, and ending in ungues, while the vibratory laminæ are greatly reduced in size.

The last limb in the *Conchæciadæ* is very minute, and consists of two little joints, the last terminating in setæ. In all the other families this limb assumes a remarkable and very distinctive character; it is long, cylindrical, and closely annulated, and thus vermiform, and is carried reflexed upwards and backwards: its extremity is divided into two lip-like lobes, which are pectinately cleft, or otherwise variously formed in the different species: around this extremity of the limb, and also on the sides at a short distance behind it, are numerous long spine-like appendages, which are themselves armed with a few aculeate projections on each side towards their extremities.

The caudal laminæ remind us of those of the *Cladocera*: they consist of a pair of plates, commonly elongated, but sometimes not so long as wide, their margins beset with numerous ungues, which gradually increase in length to the end. In most of these families a heart is present. The *Asteropidæ* alone are provided with a series of dorsal branchial plates. The ova are carried in most genera, as in the *Cladocera*, within the shell behind the hinder portion of the animal, which is attached to the shell by dorsal and lateral muscles about the middle of its length.

Of the very remarkable genus *Heterodesmus*, described by one of us in the "Transactions of the Zoological Society" for 1865, nothing is known except the shell. It seems, however, to be nearly allied to the fossil genus *Entomoconchus*, M'Coy, and probably will be found to belong to the group *Myodocopa*.

#### Fam. 1.—**ASTEROPIDÆ**, Brady and Norman.

Shell more or less oblong or elliptical, smooth, glabrous, deeply incised in front, rostral portion widely rounded, little produced downwards; posterior extremity in ♀ well rounded; in ♂ lips of valves slightly pouting behind. Antennules short and stout, penultimate joint in both sexes furnished with an unguis, antepenultimate bearing a conspicuous sensory organ of different structure in the two sexes; apical setæ subequal in ♀, in ♂ two of these setæ are excessively long. Mandibular foot very strong; basal joint with a large, reflexed, falcate masticating process, which is denticulate on the edge. First, second, and third maxillæ all thin and membranaceous, and fringed in almost all parts with setæ,

but furnished with no spines or teeth. Vermiform limb as usual. Caudal laminæ very short, the extremity beset with unguis. Seven pairs of imbricated, elongated, thin branchial lamellæ on the back of the hinder portion of the body.

The family is widely separated from other *Myodocopa* by the peculiar structure of the three pairs of maxillæ, and the presence of dorsal branchiæ.

### Genus ASTEROPE, Philippi, 1840.

(= COPECHÆTE, Hesse, 1879.\*)

Shell more or less oblong or elliptical, polished, smooth, in male rather larger than in female, and higher behind, where the edges are also more pouting. Eyes well developed in both sexes. Frontal tentacle long and slender. Antennules of female with sensory organ on antepenultimate joint terminating in a flabellately divided extremity mounted on an annulated pedicel (Pl. L., fig. 3); in male in the form of a large densely setose, robust, annulated seta (Pl. L., fig. 2). Antennæ, with swimming branch well developed, appendicular branch in ♀ small, ending in a seta, in ♂, three-jointed, formed for grasping (Pl. L., figs. 4, 10); last joint falcate, reflexed on the second. Mandibular foot strongly built; basal joint with a large falcate, reflexed, masticating process, serrated on the edge at the tip (Pl. L., fig. 6); second joint, with a backward directed lobe at the base, furnished with a few spines of very peculiar structure (Pl. L., fig. 9): limb terminating

\* M. E. Hesse, in 1879, published a paper in Ann. Sci. Nat. Zool., 6<sup>e</sup> ser., vol. vii., p. 1-20 (separate copy), pl. xii.—“Description des Crustacés rares ou nouveaux des côtes de France. Vingt-huitième article”—in which he described a genus *Copechæte* with four species, and a family *Copéchétiens*, which he placed among the Cladocera and next to the Bosminidiens. His genus *Copechæte* is undoubtedly a synonym of *Asterope*; but what his species are it is impossible, from the descriptions and extraordinary drawings, to say—possibly *Copechæte elongata* and *affinis* are referable to *A. elliptica*, Phil., and *C. armoricana* to *A. teres*, Norman.

Herr. G. W. Müller, in his recently published work, “On the Ostracoda of the Gulf of Naples and adjacent Sea,” adopts instead of *Asterope* the generic name *Cylindroleberis*, his reason for this course being, that the term *Asterope* had been proposed also by Müller and Troschel for a genus of Echinodermata, simultaneously (1840) with Philippi’s publication of the same name for the genus of Ostracoda now under consideration. It is doubtful, however, which of the two memoirs (Philippi or Müller and Troschel) was first in the field; we therefore think it best, to adhere, for the present, to the name *Asterope*, by which this genus of Ostracoda is best known. Should this name prove to be later in date than that of Müller and Troschel, we shall, of course, have to follow Herr G. W. Müller in adopting the generic term *Cylindroleberis*, which was applied to the group by one of us in 1868.

Müller and Troschel formed their genus *Asterope* to receive a starfish, which, in the same year, J. E. Gray also took as the type of a new genus, *Gymnasteria*. Sladen, in “The ‘Challenger’ Report—Asteroidea,” uses the latter name on account of the doubt in date of the two *Asteropes*; but if the Echinoderm *Asterope* antedates that of the Crustacean it must undoubtedly be used, inasmuch as Gray’s genus was not published until the end of the year (December 1).

in more than one unguis. First maxillæ (Pl. LI., figs. 14, 15) consisting of a falcate main limb ending in two setæ, beset all round the inner margin with long and slender setæ pectinately arranged; in front, from the base of this main limb, is given off a narrowly triangular membranaceous, naked lamella. Second maxillæ (Pl. LII., fig. 16) consisting of an undivided, thin, linguiform lamina, which is curiously half bent round on its axis in the female, but not so bent in the male, and setose on the inner margin; behind this is a large, semicircular vibratory lamina, surrounded by pectinately arranged, long plumose setæ. Third maxillæ in the form of a subtriangular, or shoe-shaped, undivided lamina beset throughout the greater part of the distal margin with short plumose setæ. Vermiform appendage (Pl. LII., figs. 18, 19) as usual in *Myodocopa*. Caudal lamina broader than long, with numerous ungues (Pl. LII., fig. 22), which gradually increase in length to the extremity. Dorsal branchiæ (Pl. L., fig. 1; Pl. LII., fig. 21), seven pairs of considerable size, and partially overlapping each other.

### 1. *Asterope mariæ* (Baird).

(Pl. L., figs. 1-6; Pl. LI., figs. 11-22; Pl. LII., figs. 10-15.)

1850. *Cypridina mariæ*, . . BAIRD, "Proc. Zool. Soc.," p. 257, pl. xvii., figs. 5-7.  
 1859. ,, *oblonga*, . . GRUBE, "Ueber Cypridina und ein neue Art dieser Gattung," Archiv. f. Naturges., p. 322, pl. xii. ♀ (*fide* G. O. Sars. We have not this paper).  
 1861. ,, ,, . . GRUBE, "Ein Ausflug nach Triest und dem Quarnero," pp. 101-107, pl. v., figs. 2-5, &c., ♀.  
 1867. *Cylindroleberis mariæ*, BRADY, G. S., "Synopsis of Recent British Ostracoda," Intellectual Observer, p. 127, pl. ii., figs. 11-14, ♂, ♀.  
 1868. ,, ,, BRADY, G. S., "Mon. Recent Brit. Ostrac.," Trans. Linn. Soc., vol. xxvi., p. 465, pl. xxxiii., figs. 18-22; pl. xli., fig. 1, *a-h*, ♂, ♀.  
 1887. *Asterope oblonga*, . . SARS, G. O., "Nye Bidrag til Kunds. om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," Archiv. for Mathem. og Naturvid., p. 31 (separate copy), pl. i., figs. 5-8; pl. ii., figs. 1, 2; pls. v., vi., ♂, ♀.  
 1894. *Cylindroleberis oblonga*, MÜLLER, G. W., "Die Ostracoden des Golfes von Neapel," p. 219, pl. iv., figs. 14-18, 39, 41, 49-55; pl. v., figs. 1, 4, 5, 13, 14, 33, 41-44; pl. viii., fig. 4.

Shell of the female (Pl. LII., figs. 14, 15) narrow and subcylindrical in outline, more than twice as long as high; ventral and dorsal margins almost straight and parallel throughout the greater part of their length, the arcuation being confined to the extremities, both of which are obtusely rounded; antennal sinus very narrow, but deep, situated a little below the middle of the anterior margin; valves highly calcareous, smooth, white. Seen from above the greatest width is behind the middle, whence the sides slightly converge forwards; anterior extremity narrower than the posterior.

Shell of the male (Pl. LII., figs. 12, 13) having the greatest height anterior; ventral margin straight; dorsal slightly arcuated throughout, and the declination both in front and behind less sudden than in the female; posterior extremity vertically truncate, with a slight protusion at its junction with dorsal margin. Antennal sinus much more gaping than in female, its lower margin being horizontal instead of projected obliquely forwards, which is the case in the other sex. Seen from above the greatest width is near the front, and the anterior extremity is wider than the posterior. Length of female 2.4 mm.; height 1 mm.

In the ♀ the antennules (Pl. L., fig. 3) have the second joint rather shorter than the first, and all the following successively decrease in length; first joint naked, second with one plumose seta on the inner margin, and one small seta on the side; third with seven setæ on inner margin, of which the five proximal are plumose, the two distal longer, ringed, but not plumose, outer margin with a minute spinule at the base and two ringed setæ at the extremity, this joint is subquadrate in form; fourth joint bearing, at the distal extremity of the outer margin, a sensory organ consisting of a very closely annulated basal portion, which is ultimately flattened out, and then split into six thong-like processes, which are spread on one plane; fifth joint with one small seta on the middle of distal margin, which below carries a conspicuous unguis; last joint with five annulated setæ, from which are thrown out numerous long lashes.

Antennæ (Pl. L., fig. 5) having the swimming branch bearing eleven setæ, of which four are at the extremity, the three most distant smaller than the rest, the last being minute; secondary appendage three-jointed, but apparently imperfectly segmented, last joint terminating in a seta, and another minute seta near the extremity. On Pl. L., fig. 5, we have represented an abnormal condition of this organ, which on both the antennules of the specimen from which the drawing is taken was of much larger size than usual and entirely without setæ.

The frontal tentacle (Pl. LI., fig. 11) is long and slender.

The mandible (Pl. L., fig. 6) is furnished below with a large falcate, reflexed process, the hinder margin of which is armed with four obtuse serrations, and nearer the base a single plumose seta: palp four-jointed, the first joint with three

ringed setæ on the upper margin, one in the middle, the others near the extremity, and to the extremity itself is attached a very small laminar appendage ending in two small setæ; below, the proximal corner is produced backwards into a triangular lobe tipped with four small plumed setæ, beyond which are four organs of remarkable character; with a low power they look like ordinary spines, but when highly magnified it is seen that they consist of an attenuated basal portion and an expanded spear-shaped extremity (Pl. L., fig. 6*a*); the distal half of the basal portion, moreover, is annulated and also ciliated, and the spear-shaped extremity under a very high power is seen to be tridentate; second joint of palp with a fascicle of three long, ringed, and ciliated setæ on the middle of the inner margin; outer margin of the third joint covered with setæ nine in number, the first slender, the next two stouter, after which slender and stouter setæ are arranged alternately, lower margin with three setæ at the extremity; last joint with a strong unguis above, below which are five setæ.

None of the three following organs are furnished in any part with either unguis or spines, but are invested everywhere with plumose setæ. The first maxillæ (Pl. LI., figs. 14, 15) are of remarkable form; they consist of an unjointed, gradually acuminate main member, which is bent back upon itself, so as to form a bow; the outer margin is smooth, the inner densely covered almost throughout with long plumose setæ; just before the end of the reflexed extremity the setæ cease, but the extremity itself terminates in two simple setæ; within the margin at the base is a group of setæ of larger size: on the outer side of this main member is a second in the form of a flattened, triangular, naked process, which is not half the length of the main member.

The second maxillæ (Pl. LI., fig. 16) consist of a single strap-shaped member, narrowly rounded at the extremity, fringed on the inner side with plumose setæ, and twisted half round in the middle of its length in the female, but not twisted in the male; behind this is a very large semioval, vibratory lamina, surrounded with long plumose setæ.

The penultimate limb (fig. 17) consists solely of a subtriangular or shoe-shaped plate, margined with short plumose setæ.

The vermiform limb (fig. 18) has about twelve spines of the usual character, six of which are at the extremity; these spines (fig. 19) have four pairs of spinules towards the extremity.

The caudal laminæ (fig. 22) have ten unguis, the upper five small, the following five larger, and successively increasing in size to the last.

The hinder portion of the body is furnished dorsally with seven pairs of overlapping, elongated membranaceous respiratory lamellæ (Pl. L., fig. 1).

In the male the antennules (Pl. L., fig. 2) are six-jointed, second joint longer than the first, with one large, plumose, backward-curving seta on the middle

of the upper margin; third joint triangular with six plumose setæ on upper side, three of which curve backwards; fourth joint with one seta above, and, at the extremity below, a very large sensory organ of entirely different character from that of the female, it is here a stout process, tapering to a fine extremity, very closely ringed throughout, and densely beset everywhere with fine filamentary threads; fifth joint with one small seta on the face, and at its lower corner giving support to the terminal unguis; last joint with two very stout and immensely long ringed setæ, which are beset with lashes here and there throughout their length, and three short setæ. The antennæ (Pl. L., fig. 4) have the second joint of the swimming branch equal in length to 4–5 following joints, the setæ as in ♀; appendicular branch larger than usual, forming a strong grasping organ, first joint of equal width throughout, about four times as long as wide (Pl. LI., fig. 12); second joint as long as, but wider than the first, widening from the base to the commencement of the palm, against which the unguis impinges, thence the front margin slopes backwards to the extremity, and bears in the middle three short setæ; unguis large, arcuate, widest in the middle, acute at the extremity, a seta behind its base. The mandibular foot (Pl. XLVI., fig. 13) is almost exactly as in the female, the basal joint has the same falcate process, and the second joint similar spear-shaped organs.

*Habitat*:—"Isle of Skye" (Baird). Shetland; Tobermory, in the Isle of Mull; off Tarbert, Loch Fyne, 20–60 fathoms; Valentia, Ireland; Penzance; Plymouth; Herm (A. M. N.). Cumbrae (D. Robertson). Jersey (Sinell), north-east coast of England, 25–35 fathoms (G. S. B.). Scilly Islands and Mulroy Lough, Co. Donegal (G. S. B. and D. R.).

*Distribution*.—Isle of Cherso, in the Adriatic (Grube). Spezzia, Messina, Goletta, and Syracuse, 5–20 fathoms (G. O. Sars). Bay of Biscay, at Cape Breton (Marquis de Folin). Hardanger Fiord, Norway (G. O. Sars).\*

\* *Vide* Undersøgelse over Hardangerfjordens Fauna," 1871, Vidensk.-Selsk. Forhand., p. 279. This was published subsequently to his descriptions of *A. norvegica* and *A. abyssicola*, so that, perhaps, the omission of *A. mariæ* in the list of *Ostracoda*, in his recent published paper, "Oversigt af Norges Crustaceen, II. Branchiopoda, Ostracoda, Cirripedia," Vidensk.-Selsk. Forhand. Christ., 1890, p. 15. was accidental.

2. *Asterope elliptica*, Philippi.

(Pl. LII., figs. 16, 17; Pl. LIX., figs. 19, 20.)

1840. *Asterope elliptica*, . . . "Archiv. f. Naturgesch.," p. 188, pl. iii., figs. 9-11, ♀.  
Translated "Ann. & Mag. Nat. Hist.," vol. vi.,  
1840, p. 94, pl. iii., figs. 9-11.
1887. , , Sars, G. O., "Nye Bidrag til Kunds. om Middelh.  
Invertebratfauna: iv. Ostracoda Mediterranea,"  
Archiv. for Mathem. og Naturvid., p. 28, pl. i.,  
figs. 1-4; pl. iv., ♂, ♀.

Shell in female (Pl. LII., fig. 16, 17) elliptical, well rounded at the extremities, height equal to half the length, ventral margin very slightly arcuate, dorsal rather more arched, anterior two-thirds of shell higher than posterior third, in this respect differing from *A. mariae*; antennal sinus below the middle of the front, and opening more downwards than in *A. mariae*, the rostrate anterior process overhanging it. Seen from above, the greatest width is central, and the ends nearly equal. The shell of the male, according to Sars, is both higher and broader in front than behind, dorsal margin irregularly curved; posterior extremity obtusely truncated; anterior above the antennal sinus somewhat cut away. In the female the antennules (Pl. LIX., fig. 19) have the third joint much shorter than the fourth, its distal margin concave, so that it is longer above and below than in the middle; the terminal nail is long and slender, subequal to the last two joints in length. The mandibular palp (Pl. LIX., fig. 20) not only has the peculiar spines of the infero-anteal lobe distinctly trident-formed at the extremity, but also spined or serrated on the margin of the stalk; the appendage at the end of the second joint is two-thirds as long as the third joint; the terminal unguis is long and slender, sub-equal in length to the last two joints. Caudal unguis eight pairs. Length of female, 1.5 mm.

Sars says that the terminal nail of the appendicular branch of the antennæ in the male—which we have not seen—is scarcely more than half the length of the preceding joint, and boldly curved in the middle.

*Habitat*.—Off Valentia, Ireland, 1870 (A. M. N.).

*Distribution*.—Fosse de Cap Breton (Marquis de Folin). Palermo, Sicily (Philippi). Messina, 10-20 fathoms (G. O. Sars).

3. *Asterope norvegica*, G. O. Sars.

(Pl. LII., figs. 7-9.)

1869. *Asterope norvegica*, . . Sars, G. O., "Undersøgelsen over Christiania-fjordens Dybvandsfauna," p. 53.

The following are the describer's characters of the species:—

Shell of female smooth, elongated ovate or elliptical; greatest height sub-equal to half the length; ventral and dorsal margins equally convex; obtusely rounded at both extremities. Seen from above, narrowly ovate; greatest width rather behind the middle; extremities obtuse. Antennal sinus situated nearly in the middle of the anterior extremity, very narrow, inclining obliquely upwards. Eyes distinct; antennules very strongly built, composed of six articulations, the first the longest, the second rather longer than the following, upper margin with one densely ciliated seta which curves backwards; third and fourth imperfectly jointed with five setæ on upper margin; penultimate joint with a short annulated sensory appendage furnished, at the extremity, with six olfactory papillæ; last joint terminating in a strong unguis and six short setæ. Antennæ of the usual form, natatory branch composed of nine articulations, the setæ long; first joint scarcely longer than the length of the rest combined; appendicular branch very small, indistinctly three-jointed, with one terminal seta. Mandibular feet short and robust; basal joint (the mandible itself) large and thick, not provided with any biting processes; second joint with a short lobe on the inner side armed with six "aculei"; distally above, with a small laminar appendage and two ciliated setæ; penultimate joint short, scarcely twice as long as broad; upper margin beset with about six thick annulated setæ; last joint very small, armed with a nearly straight unguis and four setæ. . . . Vermiform appendage with ten unequal spines. Caudal laminæ very small, as broad as long, armed with five unguis which rapidly increase in length towards the extremity, and above the unguis two short setæ. Colour white; length 1.34 mm.

Holmestrand, in the Christiania Fjord, Norway, in 50-60 fathoms, muddy bottom (G. O. Sars). Our figures are taken from specimens for which we are indebted to Professor Sars.

4. *Asterope abyssicola*, G. O. Sars.

(Pl. LII., figs. 18, 19.)

1868. *Asterope abyssicola*, . . Sars, G. O., "Nye Dybvandserustaceer fra Lofoten," Vidensk.-Selsk. Forhand, p. 170.

Shell of female, seen from the side, elongated-ovate; greatest height rather in front of the middle, equal to rather more than half the length; ventral and dorsal margins somewhat irregularly arched, hinder extremity evenly rounded; anterior extremity higher, and roundly-truncated; antennal sinus very narrow, situated slightly below the middle, slightly inclined upwards. Seen from above the form is narrowly ovate, more attenuated in front than behind, greatest width central and less than the height. Valves glabrous, shining, white, altogether destitute of hairs. Eyes wholly absent. Antennæ, mandibular foot, and maxillæ almost exactly as in *A. norvegica*, but the vermiform appendage furnished with more (15-16) spines. Caudal laminæ short, armed with five ungues, increasing in length towards the extremity. Length, 1.32 mm.

Very rare, Lofoten Islands, in 120 fathoms (G. O. Sars).

The above are the characters given by Sars for the species, and our figure of the shell of the ♀ is taken from a specimen kindly given to us by the describer.

5. *Asterope teres* (Norman).

(Pl. L., figs. 7-10; Pl. LII., figs. 20, 21.)

1861. *Cypridina teres*, . . . NORMAN, "Contributions to British Carcinology," Ann. & Mag. Nat. Hist., ser. 3, vol. viii., p. 8 (separate copy), pl. xiv., fig. 10.
1867. *Cylindroleberis teres*, . . BRADY, G. S., "Intellectual Observer," p. 128.
1868.       ,,       ,, . . BRADY, G. S., "Monograph Recent British Ostracoda," Trans. Linn. Soc., vol. xxvi., p. 465, pl. xxxiii., figs. 6-9; pl. xli., fig. 2.
- (?) 1876. *Asterope oblonga*, . . CLAUS (*nec* GRUBE), "Untersuchungen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems, p. 92, &c., pl. xvii., figs. 1-10.

1894. *Cylindroleberis teres*, . . MÜLLER, G. W., "Die Ostracoden des Golfes von Neapel," p. 220, pl. iv., figs. 13, 30; pl. v., figs. 15, 24, 25; pl. viii., fig. 5.

Shell of female (Pl. LII., figs. 20, 21) regularly oval, greatest height rather behind the middle, equal to fully two-thirds of the length; ventral and dorsal margins both well arched throughout, the latter rather more boldly than the former; posterior extremity very broadly and evenly rounded; anterior extremity narrower than the posterior; antennal sinus very narrow and shallow, situated below the middle, and nearly erect; rostral process moderately wide at the extremity, and bending over the antennal notch. Seen from above the form is more tumid than in other species of the genus; greatest breadth near the hinder extremity, which extremity is much broader than the anterior, and well rounded, sides arcuately sloping forwards. Surface of valves white, polished, finely punctated, glabrous. Length 1.6 mm. Third joint of the antennules (Pl. L., fig. 8) much shorter than the fourth, divided diagonally so as to form two triangular joints, the outermost of which bears eight closely-packed marginal setæ; sensory organ as in *A. maricæ*; unguis long and slender, its edge crenated; terminal setæ very long, the setæ themselves terminating in lashes of similar character to those which spring from their sides. Appendicular branch of antennæ papilliform (fig. 7), scarcely more than twice as long as its greatest width, indistinctly articulated, the end rounded, and bearing a long terminal seta, which is the only seta the limb bears. Laminar appendage of first joint of mandibular palp well developed, equal in length to two-thirds of the second segment, and its apical setæ stretching forward over the third segment. The first maxillæ are distinctly jointed at the union of the ciliated portion with the naked extremity. Caudal laminæ more than twice as broad as the length in front, the arch of the extremity, which is formed by the posterior and distal margins, surrounded by ten ungues, which gradually increase in length, the larger ungues marginally ciliated.

In the male the antennules have one recurved plumose seta on the second joint, six on the short triangular third joint, which is longer than the fourth joint on the front margin, but excessively short on the hinder margin; the large brush-like sensory organ, and the two long terminal setæ as usual. The antennæ, apparently, have only one seta on the second joint of the appendicular branch, the falcate last joint of which is equal in length to half the preceding. The terminal unguis of the mandibular palp is long and slender, equal in length to the two preceding joints; the penultimate joint has seven spines and setæ on the front margin, and a transverse group of small setæ on the face (as in *A. maricæ*). The vermiform limb has both of the apical lips serrately divided, and bears twelve spines. The ungues

of the caudal laminae are six, and above two ringed setae take the place of ungues, ranging with the rest.

We are unable to say in what slight respects the shell of the male differs from that of the female. Among a series of dried specimens of this species from off Valentia, Ireland, was a specimen larger than the rest, and larger than any other that we had seen of the species. On this account, supposing it at the time to be a female, it was macerated and dissected, the shell being destroyed. It was then discovered that the sex was male.

*Habitat*.—The Minch; Oban, 7–20 fathoms; Lamash Bay, Arran, N.B.; Tobermory, in the Isle of Mull; off Valentia, Ireland (A. M. N.). Guernsey (late J. G. Jeffreys, in Mus. Nor.). Cumbræ (D. Robertson). North East Coast of England, 25–35 fathoms (G. S. B.). Scilly Islands; Mulroy Lough, Co. Donegal; and Lough Swilly (G. S. B., and D. R.)

*Distribution*.—Naples (G. W. Müller).

## Fam. II.—CYPRIDINIDÆ, Baird, 1850.

Shell either smooth, hispid, pitted or roughly sculptured, having a deep incision in front for the protrusion of the antennæ; in front of the incision the anterior extremity is projected in rostrate or subrostrate form; infero-posteal corner often pouting, sometimes produced into a distinct process. Antennæ with secondary branch small, sometimes rudimentary in ♀, in ♂ rarely as in the other sex, but usually much larger, and formed for grasping. Mandibular foot five jointed, terminating in ungues. The following limbs maxilliform, the first furnished with three setiferous lobes and a small appendage; last joint of palp terminating in setae and unguiform setae. Second maxilla with setose lobes, one of which is also furnished with an overlapping series of strong teeth, and beyond this a palp, consisting of three or fewer lobes, outside which is a large semicircular setiferous, vibratory lamina. The last of these maxilliform limbs is smaller, composed of setiferous lobes, four in number when all are developed, and a subtriangular seta-margined, thin, vibratory lamina. Vermiform limb as usual in the *Myodocopa*. No branchiæ. Caudal laminae oval or subtriangular, armed with numerous ungues.

# DIAGNOSIS OF GENERA BY THE ANIMAL.

- Mandibular palp ending in a single unguis; penultimate joint shorter than antepenultimate, . . . . . *Nematohamma*.
- Mandibular palp ending in more than one unguis, though one sometimes larger than the others; penultimate joint much longer than antepenultimate.
- Upper tooth of second maxillæ narrow, falcate, denticulated on inner margin.
- Masticating process at base of mandible entire, . . . *Cypridina*.
- Masticating process at base of mandible cleft, . . . *Crossophorus*.
- Upper tooth of second maxillæ large, triangular, smooth-edged, . . . . . *Philomedes*.
- Upper tooth of second maxillæ subquadrate, broadly truncate at the end, smooth-edged, . . . . . *Tetragonodon*.
- Upper tooth of second maxillæ very large, oblong, with fang-like process at one end, and dentated processes at intervals on its long extremity, . . . *Paramekodon*.

N.B.—The animal of *Streptoleberis* unknown. For the shell see figures of the species.

## COMPARISON OF THE LIMBS IN THE FAMILIES CYPRIDINIDÆ, RUTIDERMATIDÆ, AND SARSIELLIDÆ.

The eyes consist of a pair, usually well developed in both sexes, but larger in the males, sometimes small or absent in the females, and between these a median ocellus, in front of which is projected a tentacular organ, sometimes short and fusiform as in *Cypridina*, more commonly elongated and filiform as in *Philomedes*.

The antennules (Pl. LV., fig. 1) consist of 5–7 joints, and are geniculated at the end of the first joint. The last joint, to which most of the terminal setæ are attached, is always very short; the proportionate length of the remaining joint varies in the different genera. At the distal end of the inner margin of the antepenultimate joint is usually attached a conspicuous sensory organ. This organ varies greatly in the different species, and affords good generic character. In *Cypridina* it is alike in the two sexes (Pl. LV., fig. 3), and in the form of a large, closely-annulated seta, bearing rather short and stiff filaments pinnately arranged

in double file. In *Crossophorus* a similar organ is present in the two sexes (Pl. LIII., fig. 2), but here it is densely filiferous. In *Philomedes* the sensory organ is absent in ♀ (Pl. LVII., fig. 12), but similar in character to that of *Crossophorus* in the ♂ (Pl. LVII., fig. 1). In *Nematohamma* ♂ it consists of a very short clavate stem (Pl. LIII., fig. 12), the termination of which is closely beset with an immense number of slender filaments of extraordinary length and great flexibility, and to the clavate stem there also is attached a long, closely-annulated seta. The females of *Tetragonodon*, *Paramekodon*, *Sarsiella*, and *Rutiderma*, have no sensory appendage, its usual place being occupied by either a simple, or an annulated seta. The terminal setæ of the limb in the ♀ are ringed, and three or more are usually subequal in length. In ♂ they undergo for the most part various modification; in *Nematohamma* they are similar to those which usually occur in the other sex; and in *Crossophorus* there are also four long setæ subequal in length; but in the genera *Philomedes* and *Cypridina* two setæ are of excessive length, more especially in *Philomedes*, in which genus these long setæ are usually carried reflexed upon the limb (Pl. LI., fig. 4). In *Cypridina* a further peculiar modification takes place (Pl. LX., figs. 19–21), two setæ, of much less length, are bulbously swollen at the base, and bear a flattened spine-like process to the side of which are attached one or two circular, saucer-like sucking disks; moreover, the longer setæ throw off strap-formed processes from their side, some of which processes are also furnished with sucking disks.

The antennæ (Pl. LV., fig. 4) consist of a basal joint of prodigious size, and one or two branches; the great basal joint is subcordate or pyriform, its breadth in some genera exceeding the length. To the end of this basal joint is attached the well-developed swimming branch, which consists of nine joints, the first very long, the remaining joints short, but the third in ♂ is often longer than the second. Each joint from the second to the eighth is furnished with one long, ringed, plumose swimming seta, but sometimes in the female the setæ are shorter than in the male, and sparingly setose; the last joint ends in 2–4 similar setæ. Springing from the end of the basal joint, below the origin of the swimming branch, is usually in the female a second (appendicular) branch of much smaller size, but this branch appears to be wholly absent in *Rutiderma*. In *Paramekodon* it is represented by a very large, ringed, plumose seta, near the origin of which are three very small, ringed setæ. In *Sarsiella* and *Tetragonodon* it consists of one minute papillary joint, bearing a seta. In *Cypridina* and *Philomedes* the development is greater, the organ consisting of at least two small joints furnished with setæ. In the male this branch attains usually greater development (Pl. LVII., fig. 2), and assumes the form of a grasping organ, usually three-jointed, with the last of these joints more or less curved or falcate, and capable of reflection on the penultimate joint; but in the genus *Cypridina* it does not differ from that

of the female. The absence of the grasping organ in *Cypridina* is remarkable, accompanied as it is in that genus by the presence of sucking-disks on the male antennules; and it would seem to be a reasonable conclusion that whereas in *Philomedes*, &c., the female is grasped by the prehensile organ of the antennæ, she is in the case of *Cypridina* held by the sucking-disks of the antennules.

Remarkable modifications are characteristic of the mandibular organ, the palp of which may consist of 2-4 joints. The mandible itself is often furnished with what has been called a "mandibular process." This process in the genus *Cypridina* is in the form of a small securiform, entire, setose lobe (Pl. LV., fig. 6), and is present in both sexes; in most other genera the lobe is cleft either almost to the base, or only a little way down (Pl. LIII., fig. 4). It is remarkable, if it assists in mastication, that a divided hirsute lobe of this kind is present in ♀, but not in ♂, in the genus *Philomedes*, and that in the male of this genus the masticating spines, presently to be described, are also absent, while *Crossophorus* has an exactly similar lobe present in both sexes. *Rutiderma* ♀, *Paramekodon* ♀, and *Tetragonodon* ♀, are furnished with a cleft process, but in *Sarsiella* ♀ it is altogether absent. The first joint of the palp in all cases where the basal joint is furnished with a masticating process, bears on its lower margin "masticating spines," which are of peculiar and varied structure in different genera (Pl. LIII., fig. 4 a). The extremity of this joint above has usually a small laminar appendage; the two final joints vary greatly, and afford good generic character. In *Cypridina* the penultimate joint is long, about equalling the two preceding joints, gradually attenuating from the base to the extremity, and densely setose above. In *Crossophorus*, *Philomedes*, and *Tetragonodon*, the joint is also long and densely setose above, but scarcely attenuated. In the preceding genera the last joint ends in several setæ and two or more unguis of moderate length. In *Paramekodon* the penultimate joint is also very long, with a dense fascicle of seta on the upper margin, and the limb terminates in a slender curved unguis of remarkable length. In *Nematohamma* and *Sarsiella* (Pl. LX., fig. 10) the penultimate joint is very short, less or not more than half the length of the preceding. In the former genus it bears only one large, annulated seta on the upper, and one similar seta on the lower margin, and the limb ends in a single large unguis, but no setæ, the unguis nearly equalling in length the last three joints. In the latter genus there are no setæ on the three terminal joints, each of which supports an unguis, which in consequence of the extreme shortness of the last joints are brought close together, each unguis being successively longer than the preceding. Lastly, *Rutiderma* possesses a limb of entirely different structure (Pl. LVIII., fig. 14); the last three joints are coalesced into a joint of extraordinary massiveness, which gives support at its extremity to a large chela, the finger

and thumb of which are very strong, forming a grasping organ, the inner edge of the lower claw being finely serrated.

The first maxillæ are furnished with three seta- or spine-tipped lateral lobes, and a terminal, usually two-jointed, palp (Pl. LIII., fig. 5). The first joint of the palp is usually of some length, the last short, bent inwards, and ending variously in setæ, spines, and unguis.

The second maxillæ are always furnished outwardly with a semi-elliptic, thin, vibratory lamina, set all round with long, plumose setæ. The limb itself attains its maximum development in *Cypridina* and *Crossophorus* (Pl. LIII., fig. 6), and consists of three small lobes fringed with spiniform setæ of varied structure, followed by a fourth lobe which, besides setæ, is armed with a series of five or six teeth, overlying each other, the uppermost being the largest. The teeth (Pl. LIII., fig. 6*b*) are narrow, upright, slightly curved at the tip, and strongly denticulated on the inner edge. Beyond this tooth lobe a fifth may be made out, which is edged with stiff spine-like setæ, many of which are serrated at the edge. Beyond this again is a three-lobed palp, each lobe ending in setæ. In other genera several of these lobes are difficult to distinguish, or altogether absent, and the palp, though always present, is sometimes represented by only one lobe. But it is desirable to notice the teeth further, for they have every appearance of being really teeth, and often of powerful structure for use in mastication, and the exact form of these teeth is very characteristic of different genera. In *Philomedes* the outermost tooth is wide at the base, somewhat triangular, and smooth on the edge; the teeth, however, which underlie this are denticulately edged. In *Tetragonodon* (Pl. LVIII., fig. 6) the tooth is of very large size, occupying the greater part of the end of the member, subquadrate in form; broadly truncate at the end and smooth-edged. In *Paramekodon* (Pl. LIX., fig. 8) it assumes the shape of a long oblong, the long side being uppermost; at one end of this oblong rises a fang-like elevation, smooth on the edge, and at intervals beyond this the tooth-plate give out three processes, each cleft at its apex into two, three, or four points. In *Rutiderma* (Pl. LVIII., fig. 15) the tooth is trifid, with smooth edges. In *Sarsiella* there are no teeth, or even spine-like setæ, but only ordinary setæ on the limb.

The third maxillæ, when most fully developed, as in *Crossophorus* (Pl. LIII., fig. 7) and *Cypridina*, consist of four small, seta-bearing lobes, behind which is a triangular seta-edged, thin, vibratory lamina. The organ in other genera becomes more and more simplified, until in *Sarsiella* the vibratory lamina and the lobes are all represented by a single lobe.

The vermiform appendage is very constant in general character, the chief difference being found in the exact structure of the terminal lips.

Genus 1. CROSSOPHORUS, G. S. Brady.

("Report 'Challenger' Ostracoda," 1880.)

Shell in general form as in *Cypridina*, the hinder extremity in the type species very broadly rounded; texture firm and calcareous; antennules with second joint only slightly longer than the third, which on the front side is much longer than the fourth, and equal to the fifth joint, this latter in both sexes furnished with a long filiferous sensory seta; sixth joint very short; last joint in both sexes terminating in three long setæ and several shorter ones. Antennæ have the appendicular branch in ♀ three-jointed, the last joint terminating in a long seta, and in ♂ like that of *Cypridina*, of much larger size formed for grasping, the last joint falcate, and closing with the second. Mandible having a cleft, setose masticating process, and also masticating spines on the first joint of the palp; both masticating process and spines present in the two sexes. Second maxillæ have several upright teeth, curved at the apex, with denticulated edge, as in *Cypridina*. Caudal laminæ furnished with stout ungues alternating with others of much more slender and spine-like character.

This genus approaches nearest to *Philomedes*, from which it is distinguished by the proportionate length of the joints of the antennules, by their having the sensory filiferous appendage present in both sexes, and by the male having the last joint setose in the same way as in the female, instead of bearing the two remarkably long setæ characteristic of *Philomedes*. The peculiar arrangement of the armature of the caudal laminæ is unlike that of any other known genus.

**Crossophorus imperator**, G. S. Brady.

(Pl. LIII., figs. 1–11.)

1880. *Crossophorus imperator*, . . . BRADY, G. S. "Report 'Challenger' Ostracoda," p. 158, pl. xxxviii., figs. 1–10.

Shell firm, porcellanous, and polished; seen from the side very broadly and regularly oval; height equal to three-fourths of the length; antennal sinus of moderate size, and expanded laterally so as to produce two obliquely-placed depressed areas on the anterior surface of the shell; rostral process curved downwards, and sharp; posterior extremity very broadly rounded; dorsal and ventral margins equally convex, not the slightest angularity on the infero-posteal portion of the shell. Seen from above the form is oblong-ovate, widest in the middle, subacuminate in front, and rounded behind; width equal to more than half

the length; end view ovate. Length of Pacific ♂ 8.4 mm. Length of Atlantic ♀ 7 mm.; height 5.8 mm.

Antennules in ♀ (fig. 2) have the second joint only slightly longer than the third, which on the front side is much longer than the fourth, and equal to the fifth; sixth and seventh very short; second joint with eight anterior, two lateral, and four posterior simple setæ; third joint with seven anterior and two posterior setæ; fourth with three distal anterior and three distal posterior setæ, this joint is considerably longer on the anterior than on the posterior margin; fifth bearing on the distal posterior extremity a long-ringed seta, beset on all sides with sensory filaments; sixth with one long and one small ringed seta; last joint with two long, and four short ringed setæ of varied form; the three longest setæ (one on penultimate and two on last joint) have long cilia here and there as usual in these setæ. Antennæ having the swimming branch furnished with twelve setæ, the last joint being very broad and bearing five of these setæ; a spine at the base of each seta; the lowest seta is short, but not spinose on the edge; the appendicular branch (fig. 3) in ♀ of similar character to that of *Cypridina*, consisting of a short, basal joint which has about five small setæ, a second much longer joint with one distal seta, a third which tapers to a point as a long, slender, ringed seta.

Mandibular limb (fig. 4), furnished at the base with a cleft, hirsute process, similar to that in the genus *Philomedes*, present in both sexes; at the base of the first joint of the palp are two spines which have five or six spinules on the upper part of one side (fig. 4 *a*); there are also six setæ on the distal portion of the front margin, whence also springs a bisetose appendage, which extends beyond the short following joint, on the hinder margin is also a single, greatly developed, ringed and ciliated seta, which equals in length the whole of the rest of the limb; second joint of palp very short, fully twice as wide as long, hinder margin with a fascicle of six setæ of various lengths, some of which are ringed and ciliated; third joint of equal width throughout, and three times as long as wide, front margin densely clothed with setæ, hinder margin with a group of about six setæ at the extremity; last joint terminating in two, long, equal nails, and two or three small setæ. The four succeeding limbs bear a close general resemblance to the same organs in *Cypridina*. The first (fig. 5) has three lateral lobes wider than usual, and over-lapping each other, each furnished with many terminal setæ; the palp is three-jointed, with one seta at the end of the first, and two at the second joint; last joint broad at the extremity, ending in several ungues and setæ; second maxillæ (fig. 6), having the tooth-lobe furnished with very strong falcate teeth (fig. 6 *b*), graduated in length from the largest and uppermost to that which is most deeply seated; the teeth are denticulated on the inner face; vibratory lamina with more than ninety marginal setæ.

The vermiform last limb is small; at the extremity one lip is in the form of a blunt tooth (fig. 8); the other is divided into several (six?) finger-like curved processes, which are ciliated on the edges; the spines are numerous (twenty counted), scattered for some distances along the limb; at their extremities (fig. 9) they bear two or three pairs of spinules, and the extremity is drawn out to a long and very fine termination beyond the last pair of spinules. Caudal laminæ (fig. 10) with seven chief unguis, which are crenated on the edge, and thirteen others of much more slender form; the arrangement of these is unusual; commencing from the base, we find first six slender seta-like unguis, then a distinctly larger one (the first and much the smallest of the seven large unguis, the six following gradually increasing in length) followed by a setiform unguis, then a large unguis, setiform unguis, large unguis, two setiform unguis the posterior the larger, large unguis, two setiform as before, large unguis, two setiform as before, and then two terminal large unguis, of which the penultimate is the longer.

*Habitat*.—The type specimen, a male, was dredged by the “Challenger” Expedition, Stat., 168, which is a little to the East of New Zealand, lat.  $40^{\circ} 28' S.$ ; long.  $177^{\circ} 43' E.$ , in 1100 fathoms, bottom temperature,  $2^{\circ} O. C.$ ; bottom, gray ooze. The second specimen, from which the animal is here described, and the drawing made is a female, which apparently differs in no respect from the male except in sex, was procured by the “Porcupine” Expedition of 1869, in the Atlantic, west of Donegal Bay, Ireland, Stat. 20, lat.  $55^{\circ} 11' N.$ , long.  $11^{\circ} 31' W.$ , in 1443 fathoms, bottom temperature  $37^{\circ} Fahr.$  It is interesting to observe, that though the two specimens were found so very far apart, the temperature of the water only differed by  $1\frac{1}{2}$  degree, since  $2^{\circ} C.$  equals  $35.6 Fahr.$

## Genus 2. CYPRIDINA, H. Milne-Edwards, 1838.

In Lamarck, “Hist. des Anim. sans verteb.,” vol. v., p. 178 (including subgenus *Pyrocypris*, W. Müller).

Shell, ventricose, never sculptured, oval; only slightly differing in the sexes; antennal sinus opening downwards, overhung in front by the rostrate process, which bends downwards; sinus much contracted by a thin lamina—an extension of the inner margin of the shell—which surrounds it; the hinder extremity may be angled, or have the antero-posteal corner with or without pouting lips.

Eyes well developed. Frontal tentacle short, usually fusiform. Antennules (Pl. LV., fig. 1) seven-jointed, in both sexes furnished with a large sensory organ at the hinder extremity of the antepenultimate joint, but of entirely different form in the two sexes; last joint ending in many setæ, of which three are primary; in the male (Pl. LX., figs. 19–21) two of the setæ possess basal

appendages which are bulbously swollen at the point of origin and above form a somewhat sword-shaped, flattened and acutely-pointed spine, the face of which has an angulated prominence near the apex, and towards the base a saucer-shaped sucking disk; the setæ themselves are also furnished at intervals with slender lateral filaments, some of which give support to several saucer-shaped sucking disks of similar character to, but very much smaller than those of the basal processes. Antennæ (Pl. LV., fig. 4), with the third joint not longer than the second in both sexes, the appendicular branch is also alike in the sexes, small, three-jointed, and terminating in a straight seta. The mandibular foot (Pl. LV., fig. 6) has a securiform, hirsute, undivided masticating process on the basal joint, and present in both sexes; no forked spines on the first joint of the palp, to the end of which joint is attached above a short lobe usually ending in two setæ; the penultimate joint is long and slender, gradually narrower towards the extremity, its upper margin densely ciliated; last joint very short, ending in three nails. The first maxillæ (Pl. LV., fig. 7) have three setiferous lobes at the base; to the end of the ante-penultimate joint is attached another lobe bearing three setæ; the penultimate joint is very broad, and as long as the preceding portion of the limb; the last joint is very short, and terminates in many spines and setæ of varied character. The second maxillæ (Pl. LV., fig. 8) have four (or five?) lobes margined with variously formed setæ; the penultimate of these lobes is the chief masticating organ, having six upright, somewhat falciform teeth graduated in length from the outermost to the innermost, and all denticulately cut on their inner edge; the outer lobe bears stout setæ, which are pectinated on one side; beyond these lobes, is a palp divided into three portions, the central being the wider, furnished with several setæ, while the inner ends in three, and the outer in two setæ; beyond is a large semicircular seta-edged, vibratory lamina. The penultimate limb (Pl. LV., fig. 9) has three (four?) setiferous lobes, and outside of these a sub-triangular seta-edged vibratory lamina. The last vermiform, ringed limb (Pl. LV., fig. 10) is furnished with numerous spines, which are as usual spinulated at their extremities. The caudal laminæ (Pl. LV., fig. 11) are of the usual structure of *Myodocopa*.

1. *Cypridina norvegica*, Baird.

(Pl. LIV., figs. 7, 8; Pl. LX., figs. 19–21.)

1860. *Cypridina norvegica*, . . BAIRD, "On some New Species of *Cypridina*,"  
Ann. & Mag. Nat. Hist., vol. vi., p. 139.
1860. ,, ,, . . BAIRD, "Note on the Genus *Cypridina*, with a  
Description of some New Species," Proc.  
Zool. Soc., p. 200, pl. lxxi., figs. 4, 4a–d.
1865. ,, ,, . . SARS, G. O., "Oversigt af Norges marine  
Ostracoda," Vid.-Selsk. Forhand., p. 104  
(separate copy).
1869. ,, ,, . . NORMAN, "Last Report Dredging Shetland  
Isles," Rep. Brit. Assoc., 1868, p. 295.

Shell of female seen from the side subovate, greatest height central, extremities nearly equal, ventral and dorsal margins moderately and equally arcuated; hinder margin centrally slightly truncate or a little emarginate, infero-posteal corner completely rounded; anterior extremity, with the antennal sinus central, very narrow and shallow, directed obliquely upwards, the rostrate process small, well arched above (in continuation with the dorsal margin), acute at the extremity, and pointing slightly downwards, the junction of the lower side of the sinus with the ventral margin forming nearly a right angle, though the angle itself is rounded off; valves white, smooth, shining, and sub-transparent. Seen from above the form is elongated-ovate, the ends nearly equal, the anterior slightly more pointed; greatest width central, equal to half the length. Length 4 mm.; height 3 mm.

In the female the antennules are seven-jointed, the first two joints subequal in length, without any setæ; the third is very short, with two setæ; the fourth about twice as long as the third, with two distal setæ; the fifth somewhat shorter than the third, its outer margin naked, the inner furnished at its extremity with a long, ringed, filiferous, sensory appendage; last two joints very short, bearing five or six short setæ and three long setæ, on which are solitary cilia at regular intervals. Antennæ with swimming branch bearing eleven swimming setæ, each with a spine by its base, the lowest seta short, not plumose but spined on the proximal margin, the most distal seta very minute; appendicular branch having the first short joint with three setæ, the second longer, with a distal seta; third tapering and terminating in a very long, tapering, and ultimately very fine seta.

The mandibular limb is furnished at the base with a hirsute masticating lobe, which is not cleft; first joint of palp having one seta about the middle of the front margin, a pair of longer setæ further on, and at the extremity a single-joint laminar appendage, which is as long as the second joint and bears two setæ, the hinder margin has three setæ, and a greatly developed, ringed and filiferous sensory seta, which is longer than the whole of the rest of the limb; second joint very short, triangular, no setæ on front margin, on the hinder a fascicle of three, of which one is ciliated; third joint equal in length to the two preceding, narrow and gradually tapering distally, front margin densely setose, except the distal third, hinder margin with only three small setæ, two of which are at the extremity; last joint scarcely separable from the preceding, ending with two chief unguis, and two of smaller size.

The first maxillæ bear three lateral lobes, which partially overlies each other and end in setæ of varied form, but most of them of spine-like character, and densely ciliated; there is also a laminar appendage directed forwards, and furnished at the base with a downward-pointing lobe and ending in two setæ, a third on the front margin; the joints of the palp (which is incurved at the extremity) are furnished with numerous spines and setæ of varied structure, some of the largest being pectinated on one side. The second maxillæ end in five lobes, three of which are lateral and two terminal; they are fringed with variously-formed setæ, those of the last lobe being for the most part strongly pectinated on one side; the penultimate lobe is armed with a graduated series of six narrow, upright teeth,\* strongly denticulated on the inner margin, and curved at the extremity; beyond the last lobe, already described, is a three-lobed palp, the middle lobe the widest, ending in five setæ; the others are narrow, the lowest has three setæ, one of which is lateral and the others distal, the furthest with two distal setæ; to the outer side of the limb is attached a large semicircular thin vibratory lamina, edged all round with long plumose setæ. The penultimate limbs or third maxillæ end in three setiferous lobes, the outer side of the limb carries a sub-triangular vibratory lamina, margined at first with nine plumose setæ, beyond which the margin is simply finely ciliated, while near the further angle are three more plumose setæ.

The vermiform limb bears very numerous spines, of which there are more than twenty at the end, and 9–13 on each side, each furnished with 5–6 pairs of distal spinules. Caudal lamina armed with nine unguis, which gradually increase in length from the first to the last, and are all finely ciliated on the edge.

The male is rather smaller than the female, the general form including that of the rostrate process is as in the latter sex, but the hinder extremity differs slightly,

\* These are so buried among the setæ that they are difficult to detect, and it requires an object-glass of one-eighth to make them all out clearly, though the two upper and larger may be easily seen.

the supero-posteal corner is less abruptly rounded and more sloped away, and the infero-posteal portion is slightly produced in lip-like form. The eyes are considerably larger than in the female. The antennules terminate in four long primary setæ (Pl. LX., fig. 19), though very generally one or more of these have been broken off near the base, and exhibit signs of reproduction; the lowest setæ and the second from above exhibit marked characteristics; they are bulbously swollen at the base, and from this bulb is given off a lobe with acute termination; to the side of this lobe is attached a remarkable saucer-shaped organ (fig. 20) of considerable size, and above a second in a rudimentary state; the setæ themselves at varied intervals send out lateral long processes which run side by side with the setæ at first, but ultimately diverge; two or three of these processes (fig. 21) are furnished at their extremity with saucer-shaped organs, usually five in number, of similar character to that of the basal lobe, but very much smaller.

What purpose do these remarkable organs serve? Their form, and the circumstance that the setæ which bear them are so frequently broken off would seem to favour the view that they are sucking disks used in grasping the female. On the other hand it is possible that their function may be similar to that of the calceolæ which are so frequently characteristic of the antennules and antennæ in the males of the amphipoda. The antennæ in all respects resemble those of the female. The copulatory apparatus consists of two ovate lobes.

*Habitat*.—Only a single specimen of this species is known from British seas; it was dredged by A. M. N. off the Unst Haaf, Shetland, in 1867.

*Distribution*.—Kloster Fjord and Stoksund, both in the Hardanger Fjord, 100–126 fathoms; Florö; Trondhjem Fjord, 150–300 fathoms (A. M. N.). Lofoten Islands, 300 fathoms (G. O. Sars). The type specimen was also dredged on the coast of Norway by the late R. M'Andrew.

## 2. *Cypridina megalops* (G. O. Sars).

(Pl. LIV., figs. 5, 6.)

1871. *Cypridina megalops*, . Sars, G. O., "Undersøgelser Hardangerfjordens Fauna 1. Crustacea," Vidensk.-Selsk. Forhand, p. 278.

Female, very like *C. norvegica*, but not so large, shorter and higher in proportion, the greatest height, instead of being central, is a little behind the middle, and the shell is higher behind than in front\*; ventral margin equally arched throughout; dorsal moderately convex in the centre, less so in front, and more so

\* In *C. norvegica* ♀ the two ends are of sub-equal height, and in the ♂ of that species the anterior portion is higher than the posterior.

behind; hinder margin obtusely, and rather obliquely, truncate, the supero-posteal portion completely rounded off, infero-posteal portion the most produced, but without any sign of angularity; rostrate process as in *C. norvegica*, but projected further forward over the antennal sinus; lower margin of that sinus arcuate from the base, and at the same time sloping slightly backwards, as it unites in a bold curve with this ventral margin; valves white, pellucid, glabrous (or nearly so), and shining; seen from above the form is elongated-ovate, greatest breadth central, and equal to half the length; length, 2.3 mm.; breadth, 2 mm. The eye is very large; "the appendicular branch of the antennæ is very short, nodiform, ending in a long seta; the penultimate joint of the mandibular palp is very narrow; the third pair of following limbs has the vibratory lamina margined with fourteen ciliated setæ, the five posterior of which are separated from the preceding by a short interval; caudal laminæ of usual form furnished with eleven finely-toothed ungues."

Very rare at Utne, in the Hardanger Fjord, in 40–50 fathoms (G. O. Sars). The shell has been described from a specimen kindly sent to us by Professor Sars.

### 3. *Cypridina mediterranea*.

(Pl. LIV., figs. 1, 2 (typica), figs. 3, 4 (Var. *b*); Pl. LV., figs. 1–11 (typica).

- 1845(?). *Cypridina Edwardsii* in text, *C. mediterranea* on plate. O. G. Costa, "Fauna del Regno di Napoli," pl. iv., figs. 1–14.
1865. *Cypridina messinensis*, . . . CLAUS, C., "Ueber der Organisation der Cypriden," Zeitsch. f. wiss. Zool., vol. xv., p. 143, pl. x., figs. 1–7.
1871. *Bradycinetus Brenda*, ♂ . . . BRADY, G. S. (*nec auct*) "Review *Cypridinidæ* of European Seas," Proc. Zool. Soc., p. 292, pl. xxvi., fig. 6.
1875. *Cypridina mediterranea*, . . . CLAUS, C., "Neue Beobach. ii. *Cypridinen*," Zeits. f. wiss. Zool., vol. xxiii., p. 221, pl. xi., figs. 16'–20.
1876.       ,,       ,,       . . . CLAUS, C., "Unters. z. Erforschung der genealogischen Grundlage des Crustaceen-System.," pl. xviii., figs. 4–6, ♂, ♀.
1884.       ,,       ,,       . . . CLAUS, C., "Elementary Text-book of Zoology" (Sedgwick's translation), vol. i., p. 425, woodcuts, ♂, ♀.

1887. *Cypridina mediterranea*, . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna. iv. *Ostracoda mediterranea*," p. 36, pl. ii., figs. 3–5; pl. vii.; pl. viii., figs. 1–5.
1894. „ „ . . Müller, G. W., "Die Ostracoden des Golfes von Neapel," p. 206, pl. ii., figs. 1, 2, 4, 5, 8–20, 22–26, 33.

We are not sure what the right name of this species should be. Authors have called it *C. mediterranea*; but Costa, in the text of the "Fauna del Regno di Napoli" names it *Cypridina Edwardsii*, but in description of plate *C. mediterranea*. As far therefore as that work is concerned it should bear the former of these two names. But this was probably the species described in an earlier paper by Costa,\* which neither we ourselves, nor apparently other authors, have seen, and as the name ultimately adopted must depend on that used in the paper referred to, we here follow other authors in the use of *C. mediterranea*.

Shell of female regularly oval, greatest height central, extremities diminishing in height equally; ventral and dorsal margins equally and evenly arcuate throughout, hinder extremity with the upper portion formed by the continued equal sweep of the dorsal margin, lower portion pouting slightly in lip-like manner, but no angularity anywhere; rostral process, as in the two preceding species; antennal sinus opening obliquely downwards and forwards, lower margin arching, with continued sweep, from the bottom of the sinus to unite, without angularity, with the ventral margin—this description applies to the shell itself, not to the thin lamina, which, springing from its inner side, surrounds and contracts, as usual, the antennal sinus; valves glabrous, less strong than in the preceding species, but Sars says: "Interdum valde calcareæ et opacæ." Seen from above the form is regularly ovate, the greatest width central, and thence tapering evenly to the extremities, which are sub-equal. Length, 2.9 mm.; height, 2 mm. The eyes are rather large. The sensory appendage of the fifth joint of the antennules (Pl. LV., fig. 3) has the filaments pinnately arranged in two lines, and few in number (about ten). The small branch of the antennæ is of the same general form as in *C. norvegica*, but much smaller, its joints very short, but the terminal seta is of considerable length; the swimming setæ of the swimming branch are eleven in number, there is a spine by the base of each of the larger ones (Pl. LV., fig. 5), and the first setæ is not plumose, but spined on one side. The vibratory lamina of the penultimate limbs is triangular (Pl. LV., fig. 9), with the marginal setæ uninterruptedly

\* O. G. Costa, "Illustrazioni al genere *Cypridina* e descrizione di una novella specie Dona della Accad. Pontaniana agli Scienz. Ital.," p. 57.

surrounding the outer edge. The caudal laminae are furnished with eleven unguis (Pl. LV., fig. 11), edges of the larger unguis crenated, of the smaller ciliated.

The shell in the male very closely resembles that of the female in form, but the labiate projection of the infero-posteal portion is more pronounced, and the whole form rather more elongated. The eyes are larger than in the female. The antennules have the sensory appendage of fifth joint similar to that of the female, and bear at their extremity two long (not reflexed) setae, and also two setae which are bulbously swollen at the base, from which rises an acutely pointed spine-like process which gives attachment on the inner side to a saucer-shaped appendage: from these setae arise also long lateral processes, some of which support saucer-shaped organs, usually three in number. The appendicular branch of the antennae is similar to that of the female.

There are, apparently, two forms of this species—(a) That here described, which is the *C. messinensis*, and, subsequently, the *C. mediterranea* of Claus, and the *C. mediterranea* of Sars, of which the ♀ is figured by us (Pl. LIV., figs. 3, 4). This form we have from Naples (A. M. N.), and the Adriatic (Prof. Heller, in Mus. Nor.), Messina (Claus); (b) a form in which the shell is much less high in proportion to the length, and regularly ovate (3 mm.), with the hinder extremity regularly rounded, the greatest projection central (and no infero-posteal pouting lips). When examining the shells only we came to the conclusion that this was a distinct species, but a close comparison of the animals of the two forms showed them to be exactly alike, and therefore we do not separate them. This form is figured by us (Pl. LIV., figs. 1, 2). It was procured by us (A. M. N.) when at Naples Zool. Stat. in 1887, and appeared to be much more abundant there than form (a).

Now, this latter form (b) closely agrees with Costa's figure of *C. (Edwardsii) mediterranea*, which shows no infero-posteal labiate projection, and if it should prove distinct from form (a), must bear Costa's name. Meanwhile, we would call this form (b) *C. mediterranea* (Costa), and form (a) *C. mediterranea* var. *messinensis* (Claus). [G. W. Müller has since this was written described form *a* under the name *Cypridina squamosa*.]

#### 4. *Cypridina angulata*, G. O. Sars.

1887. *Cypridina angulata*, . . . Sars, G. O., "Nye Bidrag til Kunds. om Middelh. Invertebratfauna: iv. Ostracoda mediterranea," p. 43, pl. iii., figs. 1, 2; pl. viii., figs. 6, 7.

"Shell of female, seen from the side, rounded-oval; dorsal and ventral margins regularly arcuate, equally high at the two extremities; hinder margin

exserted below the middle, and there forming a distinct and prominent angle; rostrate projection moderately prominent, sub-truncated in front, with a distinct angle below, but not above; eyes very large; limbs little differing from those of *C. mediterranea*, length 2.62 mm."

Two females taken by Prof. G. O. Sars, at Messina, Sicily, in 10–20 fathoms. We have not seen this species.

### Genus 3. PHILOMEDES, Lilljeborg, 1853.

(= CYPRIDINA, Lilljeborg, ♀ 1853, = PHILOMEDES, Lilljeborg, ♂ 1853,  
= BRADYCINETUS, G. O. Sars, ♀ 1865.)

Shell of female more or less ovate, either smooth, hispid, or highly calcareous, and sculptured with pittings or ribs; antennal sinus usually opening downwards; rostral process obtusely terminated, overhanging the sinus; infero-posteal angle often angularly produced. In the male the shell is longer in proportion to the height, and the antennal sinus is of different form, being widely open forwards, as well as downwards, because the rostral process is here truncated anteriorly, and rises almost at a right angle from the bottom of the antennal sinus, which it does not overhang; in rugose forms, the valves also of the male are much less sculptured than in the female.

Eyes of ♀ small or wanting, of ♂ well developed. Frontal tentacle long and slender. Antennules six-jointed (Pl. LVII., fig. 12; fourth joint without any sensory organ in ♀, but in ♂ (Pl. LVII., fig. 1) with such an organ, which consists of a large annulated appendage beset with numerous filaments, extremity of the limb ending in ♀ in several subequal setæ, in ♂ two setæ are immensely developed, of very great length, and usually carried reflexed upon the limb. Antennæ with appendicular branch small in ♀ (Pl. LVII., fig. 13), but in ♂ (Pl. LVII., fig. 2) much larger and prehensile, the last joint closing on the second. Mandible of ♀ having the basal joint furnished with a masticating process which is cleft at the apex (Pl. LVII., fig. 14); first joint of palp, with peculiar formed masticating spines at the base, and furnished at the dorsal extremity with a small appendage; third joint only slightly narrowing to the extremity, last joint terminating in unguis, the ♂ is wholly destitute of the masticating process and masticating spines (Pl. LVII., fig. 3). Most of the remaining limbs and the caudal laminæ are not markedly different from those of *Cypridina*. The second maxilla, however, differ considerably in minute detail; in the female there are only four lobes, the place of the outermost lobe being occupied by a series of teeth, the uppermost of which is large and triangular, and not denticulate on the margin; beyond the tooth the group of the spine-formed setæ, and other setæ characteristic

of *Cypridina* are absent and the palp consists of only two lobes, the hindermost lobe in *Cypridina* being absent and represented here by two setæ on the limb itself. The penultimate appendages have only three lobes (Pl. LVII., fig. 6), the first lobe in *Cypridina* being in this genus absent, but represented by two setæ on the member itself; the vibratory lamina as in *Cypridina*.

### 1. *Philomedes brenda* (Baird).

(Pl. LI., figs. 1-3; Pl. LVI., figs. 1-3.)

1850. *Cypridina brenda*, . . . BAIRD, "Nat. Hist. Brit. Entom.," p. 181, pl. xxiii., figs. 1 *a-g*, ♀.
1853. *Cypridina globosa*, . . . LILLJEBORG, "De Crust. ex. ord. tribus, &c.," p. 171, pl. xvii., figs. 2-10; pl. xviii., figs. 1-3, 7, ♀.
1853. *Philomedes longicornis*, . . LILLJEBORG, "De Crust. ex ord. tribus, &c.," p. 176, pl. xxvi., figs. 4, 5, 6, 14, 15, 16, ♂.
1855. *Asterope grænlantica*, . . FISCHER, S., "Beitrag. zur. Kenntniss der Ostracoden," 1855, p. 26, pl. ii., figs. 26-34, ♀.
1865. *Bradycinetus globosus*, . . SARS, G. O., "Oversigt af Norges marine Ostracoder," Vid.-Selsk., Forhand., p. 110, ♀.
1865. *Philomedes longicornis*, . . SARS, G. O., "Oversigt af Norges marine Ostracoder," Vid.-Selsk. Forhand, p. 106, ♂.
1868. *Bradycinetus brenda*, . . BRADY, G. S., "Mon. Recent Brit. Ostracoda," Trans. Linn. Soc., vol. xxvi., p. 466; pl. xxxiii., figs. 1-5; pl. xli., fig. 5, ♀.
1869. *Philomedes globosus*, . . SARS, G. O., "Undersøgelser over Christianiafjordens Dybvandsfauna," 1869, p. 51, ♀, ♂.
1876. *Bradycinetus brenda*, . . NORMAN, "Biology 'Valorous' Cruise, 1875," Proc. Roy. Soc., vol. xxv., p. 206 (no description).
1891. *Philomedes brenda*, . . NORMAN, "Crustacea Ostracoda of Norway," Ann. & Mag. Nat. Hist., ser. 6, vol. vi., p. 119.
- [Not *Bradycinetus brenda*, . . BRADY, G. S., "Review of Cypridinidæ of European Seas," Proc. Zool. Soc., 1871, p. 292, pl. xxvi., fig. 6.]

Shell of female broadly ovate, greatest height central, equal to three-fourths of the length; ventral margin boldly and regularly arched; dorsal margin

slightly arcuate, descending suddenly in front; posterior margin rather obliquely truncate, with an angle at the junction with the ventral margin; anterior margin highly vaulted, from the summit of the vault an oblique truncation descends to form the rostrate process, which is very broad, and angled at the extremity; it overhangs the moderately deep sinus, which is distinctly inferior, and widely open, and has its lower margin nearly straight, and uniting with the ventral margin in an obtuse angle. Surface of valves everywhere pubescent, with short erect hairs. Seen from above the form is elongo-ovate, the sides evenly arched, the greatest breadth central, and equal to half the length. Length of Greenland specimens 3 mm., height 2 mm. Scandinavian and British specimens slightly less. Colour pale yellow. The antennæ in the ♀ have the tactile seta of the small branch of considerable length, and the terminal spine hook-shaped, curved, and forming a prehensile organ with the flattened joint from which it springs. The masticatory process of the mandible is very deeply divided, and the masticatory spines are furnished with a single stout lateral prong. Vibratory lamina of the penultimate limbs narrowly triangular, and edged with about fifteen setæ. The vermiform last limb (Pl. LI., figs. 2, 3) is furnished with more numerous spines than usual, of which about sixteen are at the extremity, and eleven on the sides; the distal portion of the spines is furnished with 7–8 serrations on each side. Ungues of the cauda about eighteen; the two ultimate pairs have strongly spined edges, the rest are not spined but ciliated; in the male the spinose and ciliated garniture of the unguis is more delicate than in the female.

The male has the shell of very different form than that of the female; the outline is more oblong, the height about three-fifths of the length; both ventral and dorsal margins are only slightly arcuate; the posterior extremity is rather obliquely truncated, as in the female, but the infero-posteal corner is well rounded, and devoid of the angularity of the other sex; the anterior sinus is very shallow, but widely open, the highly-vaulted anterior extremity rising perpendicularly from the bottom of the sinus thence arches backwards, so that the overhanging portion, characteristic of the female, is quite obsolete. The surface of the valves has, in addition to the pilose investiture, longer setæ sparsely distributed over the posterior portion. The grasping branch of the antennæ of the male (Pl. LI., fig. 1) has the second joint slightly curved backwards, and furnished with three closely-ringed flagella on the inner margin, the third joint is formed for reflection on the second, and arcuate in a reverse way to the latter, on which it closes; the inner face smooth, furnished with one closely-ringed flagellum near the base, and a minute seta at the tip.

*Habitat.*—Off the coast of Durham, near the Dogger Bank, 1862 (A. M. N.). “Off Noss, in Shetland, 80–90 fathoms” (M<sup>r</sup> Andrew).

*Distribution*.—Holsteinbourg Harbour, Greenland ("Valarous," 1875); Dröbak, Christiania Fjord, 30–100 fathoms; Bog Fjord, East Finmark, in great abundance, 1890; Trondhjem, 20–100 fathoms, 1892 (A. M. N.). Bergen (Lilljeborg, in Mus. Nor.). Tromsö (J. S. Schneider, in Mus. Nor.). Utne, Hardanger Fjord, 15–20 fathoms (G. O. Sars). Kullaberg, Sweden (Lilljeborg).

## 2. *Philomedes interpuncta*, Baird.

(Pl. LVI., figs. 6–10; Pl. LVII.)

1850. *Cypridina interpuncta*, . . BAIRD, "Proc. Zool. Soc.," p. 257, pl. xvii., figs. 5–10.
1861. *Philomedes longicornis*, . . NORMAN, "Ann. & Mag. Nat. Hist.," ser. 3, vol. viii., p. 280, pl. xiv., fig. 11 (nec *Philomedes longicornis*, Lilljeborg).
1868. *Philomedes interpuncta*, . . BRADY, G. S., "Mon. Recent Brit. Ostracoda," Trans. Linn. Soc., vol. xxvi., p. 463, pl. xxxiii., figs. 10–13; pl. xli., fig. 3 *a-f*, ♂.
1871.        "                "       . . . BRADY, "Review of Cypridinidæ of European Seas," Proc. Zool. Soc., p. 293, Pl. xxvi., figs. 1–5, ♀.
1894.        "                "       . . . MÜLLER, G. W., "Die Ostracoden des Golfes von Neapel," p. 210, pl. iii., figs. 1, 2, 5–16, 19, 20, 24–28, 38–44.

Shell of female sub-ovate, greatest height central, equal to about five-sevenths of the length; ventral margin well and evenly arched; dorsal margin nearly straight in the middle, in front well arching to the anterior extremity, behind suddenly deflexed to the hinder margin; hinder margin obliquely truncate, furnished with a spine process at the infero-posteal corner, which is directed backwards, and a second similar spine process at the supero-posteal corner, which is directed downwards (these spines are sometimes obsolete or rudimentary). Anterior extremity, with the rostrate portion nearly erect, the upper margin of the sinus being straight, and directed with a slight obliquity downwards; the sinus itself is thus widely open, shallow, and widely rounded at its junction with the ventral margin: surface of valves altogether devoid of any pilose covering, but when in good state elegantly reticulated, the reticulations irregularly hexagonal; in the older shells this reticulation becomes more and more indistinct, and the surface is (from many localities) curiously eroded, the erosions forming circular or irregular pittings. Viewed dorsally the form is elongated ovate, the

greatest width central, and equal to half the length; anterior extremity narrowly rounded; the posterior somewhat apiculate. Length, 1·4 mm.; height, ·8 mm. It will be observed that this is a very much smaller species than the last.

Shell of male longer and more ovate than that of the female, height rather more than half the length; both ventral and dorsal margins only gently arched, the latter nearly straight in its central portion; posterior rather obliquely truncate, as in the female, but the upper spine process usually absent, the lower usually present; rostrate anterior extremity even more erect than in the other sex, its lower margin, as well as the sinus, fringed with rather long cilia.

Antennæ of ♀ (Pl. LVII., fig. 13), with the swimming setæ much shorter than in the male. Antennæ of ♂ (figs. 2, 2 *a*), having, as usual, the third joint of the swimming branch much longer than the second; the swimming setæ eleven. The short seta, arising from the apex of the second joint, is peculiar in having its external margin armed with about ten small spines; appendicular branch with two setæ on the inner margin of the second joint; last joint very protuberant at the base, then suddenly and deeply incised; this constricted portion is succeeded by another protuberance, after which the joint slopes away in cylindrical form to the end, the cylindrical portion has usually about four minute tubercles on the edge, and there is a cilium near the extremity. In the female the appendicular branch of the antennæ has three or four small setæ on the basal joint; a long plumose seta on a second joint, and a distant slender seta on the last. Mandible in ♀ (fig. 14), having the basal forked process deeply cleft, and the masticating spines with only small cilia on the side, and no prong. Vermiform appendage (fig. 7) with very few setæ, usually six terminal and four lateral. Caudal plates narrow (fig. 8), with about eleven ungues on each; the five upper ungues are very small, the sixth about twice as long, the seventh again very small, the eighth is considerably larger and stronger than the sixth, and is followed by two terminal ungues, which are very much longer and more robust than any of the preceding.

*Habitat*.—Plymouth, 1858; off Northumberland, 1862; Shetland, 1863; Oban and Tobermory; Valentia, Ireland, 1870 (A. M. N.). Cumbrae, Firth of Clyde; Loch Long (D. Robertson).

*Distribution*.—Fosse de Cap Breton, S. W. France (Marquis de Folin).

3. *Philomedes Lilljeborgii* (G. O. Sars).

(Pl. LI., figs. 4–6; Pl. LII., figs. 3, 4.)

1865. *Bradycinctus Lilljeborgii*, Sars, G. O., "Oversigt af Norges marine Ostracoder," Vid.-Selsk. Forhand, p. 112 (separate copy).

Shell of ♀ roundedly-quadrangular, greatest height central, equal to nearly three-fourths of the length; ventral margin well, but not boldly, arched; dorsal margin nearly straight in the central portion, in front boldly arching to the rostrate extremity; hinder margin abruptly, and somewhat obliquely truncate, the infero-posteal corner produced into a much compressed and backward-directed point, anterior margin formed by the continuous sweep of the dorsal, until abruptly cut off by the almost horizontal face of the rostrate process, which is broad; antennal sinus inferior, moderately open, well-rounded at its junction with the ventral margin. Seen from above ovate, with a mucro behind, caused by the infero-posteal produced angle; greatest width central, equal to half the length, sides evenly arched. Surface of valves everywhere finely punctate, not setose, though the ventral margin is fringed with fine cilia, which attain much greater length on the margins of the antennal sinus, and front of the rostrate process. Length, 2.6 mm.; height, 1.8 mm.

The male differs from ♀ in a similar manner to that of *P. brenda*, the form being more oblong (Pl. LI., fig. 4), ventral and dorsal margins nearly straight centrally, the latter slightly emarginate; the inferior portion of the rostrate process is, as it were, cut off, the horizontal front being thrown back as far as the bottom of the sinus, which is thus widely open, and affords ample scope for the play of the large antennules; greatest height, half the length. There is a projection at the infero-posteal corner similar to that of the female, but not so strongly pronounced.

In ♀ the antennules have the second joint about equal in length to the rest of the limb. The appendage of the antennæ (fig. 6) has one seta on the first joint, and three (of which that nearest the base is long and plumose), besides the terminal hook-formed seta on the second. The forked process and masticatory spines of this sex are as in *P. brenda*. Vermiform last limbs with few, 10–12, spines. The caudal laminæ have 9–11 ungues, which gradually increase in length and size, and are strongly denticulate on the edge.

In the ♂ the antennæ have the third joint of the swimming branch, as usual, longer than the second, and there are eleven natatory setæ, the two distal of

which are very small; the appendicular branch (fig. 5) has the second joint furnished with three comparatively short setæ, the last joint has no incision; the inner face is waved, so that the diameter is greatest just before the middle, while the extremity is also wider than the part preceding. The nine ungues of the abdominal plates are ciliated, not spined on the edge as in the other sex.

*Philomedes Lilljeborgii* occurs not uncommonly in the Fjords of Norway, where it inhabits deeper water than *P. brenda*. Near Drobak, in the Christiania Fjord, 100 fathoms; Bergen Fjord, south of Bukken, 150–200 fathoms; in the Hardanger Fjord, off Lervig, 150–180 fathoms and in Stoksund, 126 fathoms; Trondhjem Fjord, 100–300 fathoms (A. M. N.) Sars's type specimens were from the first of the localities just enumerated, and he has also taken it at the Lofoten Islands. We have also specimens taken, during the second cruise of the "Porcupine," in a depth of 430 fathoms, lat.  $48^{\circ} 50' N.$ , long.  $11^{\circ} 9' W.$ ; and during the first cruise in lat.  $46^{\circ} 13' N.$ ; long.  $14^{\circ} 18' W.$ , depth 420 fathoms; for these specimens we have to thank our friend, Mr. E. C. Davison, R.N. (G.S.B.).

#### 4. *Philomedes foveolata* (G. W. Müller).

(Pl. LVI., figs. 4, 5.)

1894. *Pseudophilomedes foveolata*, MÜLLER, G. W., "Die Ostracoden des Golfes von Neapel. und der angrenzenden Meeres-Abschnitte," p. 212, Pl. iii., figs. 34, 35, 45–49, 51, 53, 54; Pl. iv., figs. 1, 2, 7.

Shell of the male ovate, truncated behind, greatest height central, equal to two-thirds of the length, ventral margin evenly and moderately arched throughout; dorsal regularly arched through its entire length; hinder extremity abruptly and scarcely obliquely truncated, infero-posteal corner angled, but not produced; anterior extremity vaulted; rostrate process rising obliquely forwards, its extremity blunt, and widely rounded; antennal sinus facing downwards, not wide, the lower side arcuately joining the ventral margin without any angularity; surface of valves everywhere pitted with conspicuous round foveolæ. Viewed from above it is of nearly equal breadth throughout its central portion, the sides being straight and nearly parallel, breadth not quite equal to half the height, anteriorly suddenly narrowed at the region of the rostrate process; posterior extremity broadly rounded; length, 1.6 mm.; height, 1 mm.

The antennules have the first joint naked, second longer than the first, and also longer than the remainder of the limb, with one seta on each margin, and

one on the side near the extremity; third joint sub-triangular, a single seta on each margin; fourth with two distal setæ on inner, and four and the sensory organ on the outer margin, the sensory seta long-ringed, the filamentous processes confined to the lower third of its entire length; fifth with one setæ; sixth with four porrected setæ, as well as the greatly developed pair of setæ which are reflexed upon the limb. The antennæ have the third joint of the swimming branch fully twice the length of the second, the swimming setæ are eleven in number, the secondary appendage is, as usual in the male sex, a well-developed grasping organ, the basal joint rather longer than broad, with three setæ, the second joint very long, with two spine-formed setæ on the middle of the inner face, the third joint as long as the second, and reflexed on it.

The mandible is without masticating lobes or spines; first joint of palp with seven long, and a few short setæ on the inner margin, and one median and two distant setæ on the outer margin, the laminar appendage small, not half the length of the following joint; second joint with a fascicle of five setæ on the middle of inner margin; third joint of nearly equal breadth throughout, its inner margin with a pair of setæ near, and four setæ at the extremity, outer margin with one or two pairs of shorter setæ near the middle, succeeded by a pair of very long-ringed setæ; last joint with two unguis, one of which is very long, above which is a spine and below a seta; the second maxillæ have the outer member of the palp bearing two plumose setæ of unusual size for that position; on the limb itself teeth seem to be absent, and their place taken by lanciform spines. The penultimate limbs have their first lobe furnished with two setæ, the second with one lateral and six distal, the third with one lateral and seven distal, while the fourth lobe is entirely coalesced with the vibratory lamina, but distinguishable by its four smaller and differently constructed setæ, the vibratory lamina itself having eight large, plumose, backwardly curving setæ. Vermiform limb with few setæ. Caudal laminæ narrow, with ten unguis, the upper six small and of uniform size, the seventh much larger, the eighth small as the first six, the ninth and tenth long and slender, ciliated on their edge, as is also the seventh. In all the specimens examined a smaller unguis is, as described, interposed between the second and fourth from the end. We have only seen the male of this species.

Males only procured from tow-net gatherings when at the Zoological Station, Naples, in 1887 (A. M. N.).

[Our description of this species was written before the publication of Herr G. W. Müller's monograph, in which it is by a coincidence figured and described under the specific name which we had ourselves assigned to it. Müller, however, takes the species as the type of a new genus—*Pseudophilomedes*—distinguished from *Philomedes* by the structure of the first and second pairs of maxillæ. It

seems to us, however, that the organs, as figured by Herr Müller, do not differ, except in the degree of development of their various parts, from those of *Philomedes*, and that other members of the genus, if such deviations were admitted as generically valid, would also require new generic names. This opinion is based, we must admit, solely on a study of Herr Müller's figures. We, ourselves, have seen only the male, while the peculiarities in question are not found except in the female.]

5. *Philomedes Mac Andrei* (Baird).

(Pl. LI., figs. 7, 8; Pl. LII., figs. 5, 6.)

1848. *Cypridina Mac Andrei*, . BAIRD, "Note on the Genus *Cypridina*, M. Edwards, with a Description of two new species," Ann. & Mag. Nat. Hist., ser. 2, vol. i., p. 21, pl. vi. *B*, figs. 1, 2.
1850. ,, ,, . . BAIRD, "Nat. Hist. Brit. Entom.," p. 179, pl. xxii., fig. 1 *a-g*.
1868. *Bradycinetus Mac Andrei*, BRADY, G. S., "Mon. recent Ostrac.," Trans. Linn. Soc., vol. xxvi., p. 468, pl. xxxiii., figs. 14-17; pl. xli., figs. *a-g*.

Shell subrotund, beyond which general form the rostrate frontal process, and the produced infero-posteal corner form projections; greatest height central, equal to two-thirds of the length; ventral margin rather strongly arched throughout its length, but much less tumid than the dorsal; dorsal margin remarkably, boldly, and continuously arched from the rostrate process right round the posterior extremity until the infero-posteal corner is reached; that corner is produced downwards into a short, compressed, triangular process, the front margin of which is crenated; anterior rostrate projection consisting of an underlying portion of thin texture (often shrivelling up when the shell is dried), and not unlike in form to the rostrate extremity in *P. Lilljeborgii*; overlying this is a raised calcareous portion, which forms, on each side, a horn-like process running out to an acute extremity, and strongly curved outwards and forwards; antennal sinus narrow, opening downwards, the upper side is slightly convex, and slopes upwards to form the horn-processes, the lower side is slightly convex, and sweeps round without any angularity to unite with the ventral margin; surface of valves ivory white, glabrous, and highly polished. Seen from above the form is broadly ovate; anteriorly the points of the rostral process are seen extended laterally like horns on each side, while the infero-posteal processes are projected backwards in

rostrate manner; greatest width central, equal to half the total length. Length, 2.2 mm.; height, 1.6 mm.

The antennules have the extremity of the larger setæ split into two or three lashes. The antennæ in the female have thirteen pulmose swimming setæ, which are of greater length than usual in this sex; the appendicular branch (Pl. LI., fig 7), has the first joint furnished with four setæ situated close together near the base, and a seta at the extremity; the second joint bears, besides the usual hamate terminal seta, four lateral setæ, of which the first and last are longer than the two in the middle. Cleft process of mandible unequally divided, the upper and shorter portion setose; masticating spines, furnished with one strong lateral prong, and two or three other minute spine-like processes on the distal margin; third joint of palp 3–4 times as long as broad. Vermiform limb with only about eight spines (fig. 8). Caudal laminæ bearing ten unguis, the tenth strongly spined on the edge, the preceding nine finely pectinated; from near the under side of the base of each unguis there springs a group of about six moderately long simple setæ. The male is unknown to us.

*Habitat.*—The Minch, 1866; off the South-west of Ireland, in 159, 183, and 722 fathoms, "Porcupine," 1869 (A. M. N.). Between Lewis and Skye, 70 fathoms (M'Andrew). Oban, and Cumbræ, Firth of Clyde (D. Robertson).

*Distribution.*—Off west coast of Morocco, 636 metres (Marquis de Folin). Fosse de Cap Breton, Bay of Biscay, 1880 (A. M. N.).

## 6. *Philomedes Folini*, G. S. Brady.

(Pl. LI., figs. 9, 10; Pl. LVI., figs. 11, 12).

1871. *Philomedes Folini*, . . . BRADY, G. S., "Review of the Cypridinidæ of the European Seas," Proc. Zool. Soc., p. 294, pl. xxvii., figs. 1–5, ♂, ♀.
1887.       ,,       ,,       . . . SARS, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," Archiv. for Mathem. og Naturvidskab., p. 48, pl. iii., figs. 3, 4; pl. ix., figs. 1–13.

Shell of female (Pl. LVI., fig. 11), seen from the side, subrhomboidal; greatest height central, equal to fully two-thirds of the length; ventral margin equally and moderately arcuate throughout; dorsal much more boldly arched, the convexity being equal from the summit of the rostrate process to the commencement of the hinder margin, where the rounded declivity is more sudden; hinder margin obliquely truncate, without angularity above, infero-posteal corner produced,

and bending slightly backwards; rostrate process in front very broad, its front margin obliquely sloping backwards to the summit, which is obtusely rounded; antennal sinus widely open, its thin marginal laminæ almost meeting each other; the sinus looks downwards, its lower margin is not convex, and sloping backwards unites at an angle with the ventral margin. Surface of valves very rugose, and boldly sculptured with elevated ribs. The lowest of these commences at the bottom of the antennal sinus, and then passes round it, and round the ventral margin, a little within its edge, to the posterior extremity. Midway between the bottom of the sinus and the point where this rib turns to pass round the ventral margin, it throws out a branch rib, which traverses the valves a little below the middle, until it nearly reaches the posterior margin; a third rib, commencing at the extremity of the rostrate process, sweeps across the valves until it comes near the summit of the hinder margin, there it is deflexed, and proceeds parallel with the hinder margin, and finally unites with the first described rib at the infero-posteal corner; a fourth and fifth rib also commence in the rostrate process, and pass backwards, the one near to, and the other on the back of the valves, at about half the length of which they coalesce, and proceed backwards near the dorsal margin as one rib (Pl. LVI., fig. 12). These last ribs are best seen when the shells are looked down upon from above. The entire surface of the valves between the ribs is pitted with foveolæ. Seen from above the form is sub-hexagonal, with nearly parallel sides, which converge suddenly and angularly towards the extremities, the anterior of which is widely and abruptly truncate, the posterior broadly and bluntly mucronate and notched in the middle. The valves are very tumid, so that the breadth is more than half the length. The end view is irregularly heptagonal, the nearly parallel lateral margins ending above and below in prominent rounded angles, the two superior margins converging into an irregular arch; the basal margin nearly flat. Length 2.6 mm.; height 1.7 mm.

The antennules end in six long and some short setæ. The smaller branch of the antennæ has six setæ at the base, on the middle a great plumose, annulated, sensory seta (Pl. LVI., fig. 10), and a minute curved spine-like seta at the extremity; the swimming branch bears fourteen setæ. The frontal tentacle is of great length, and slender. The mandible has the masticating lobe as usual, bifid and hispid, and the masticating spines have one strong lateral prong, with more slender spine-points beyond it. The second maxillæ are indistinctly four-lobed, the first three lobes beset densely with setæ, fourth lobe having the outer tooth-process very large and strong, often with a lobe above near the base; inner edge plain, that is, not denticulated, the succeeding and underlying series of teeth gradually diminishing in size, all with their inner edge denticulated, and some setæ springing from base of the large tooth; beyond is the palp, which is

two-lobed, the first lobe ends in two, the second and larger in six setæ; beyond this lobe are two setæ on the body of the limb, which setæ appear to represent the third lobe of the palp, which is present in *Cypridina*; the vibratory lamina is as usual. The triangular vibratory lamina of the penultimate limbs is fringed with about fifteen plumose setæ, uninterruptedly arranged around the outer border. The vermiform last limb bears only about ten spines, six at the end, and four on the sides; at their extremity these spines are furnished with 4–6 pairs of spinules. The caudal laminae bear thirteen ungues, of which the four last are much larger than those preceding.

The shell of the male (Pl. LI., fig. 9) is much smaller and lower in proportion to its length than that of the female, and also less tumid. The rostrate process, as usual in males of this genus, is more erect, the inferior portion being absent, and consequently the antennal sinus is much more widely open. The surface of valves is pitted with foveolæ, as in the other sex, but the great ribs are almost entirely absent. A faint trace of one remains near the antennal sinus, and the second and third rib are developed, but only on the hinder portion of the shell, while the first, fourth, and fifth ribs are entirely absent. The height is somewhat less than half the length. The antennules have a large sensory seta at the hinder extremity of the fourth joint, this seta is annulated, and densely ciliated on one side of its swollen basal portion; at the extremity are two very long, annulated setæ, which are, as usual, generally reflexed upon the limb, and five other short setæ. The appendicular branch of the antennæ has the first joint short, the second long, and arcuated backwards, with three setæ on the front margin; the last joint nearly equals the second in length, and is so bent as to impinge upon that joint; on its inner face are some very minute backward-directed teeth, and at the extremity two microscopic setæ; the second seta of the swimming-branch is separated by the interval of a long joint from the first. The mandible, as appears to be universal in males of this genus, has no appearance of either the “masticating” process, or the “masticating” spines.

Fosse de Cap Breton, Bay of Biscay (Marquis de Folin, 70 fathoms, and A. M. N., 1880, in 35–65 fathoms); Messina, 10–12 fathoms (G. O. Sars).

#### Genus 4. STREPTOLEBERIS, G. S. Brady, 1890.

(Brady, “Ostracoda collected in the South Sea Islands.”—Trans. Roy. Soc., Edinburgh, vol. xxxv., p. 515.)

Shell, seen from the side, elongated, flexuous, somewhat S-shaped; rostrate process much produced forwards, the notch being on the ventral aspect of the shell; posterior extremity narrower, produced into a pointed terminal beak, directed backwards. Animal unknown.

(Type, *Streptoleberis crenulata*, G. S. Brady, from Nouméa.)

The animal is unknown. We had hoped from the appearance of two dried specimens of *S. favosa*, that they might have been alive when dredged. These were carefully softened and examined, but such fragments of the animal as remained were only the relics of one which had been dead when dredged, and very dirty. One or two minute fragments of limbs seem peculiar, the caudal laminae had only six ungues, all of considerable size, and one of them (detached but probably the last) shows a large and conspicuous spine-shaped process on the middle of the outer margin, both the inner and outer margins beyond the spine-shaped process being ciliated. The antennae resemble most closely in character the same organs in *Paramekodon*, having no appendicular branch but two setae in its place, the basal joint somewhat smaller than usual, the length exceeding the breadth, first joint of the swimming branch rather slender.

1. *Streptoleberis favosa*, n. sp.

(Plate LIX., figs. 16–18; Plate LXII., figs. 20, 21.)

It is difficult to apply any term to the curious outline of this species, but it may perhaps be said that the portion posterior to the antennal sinus is in the shape of a cone, of which the hinder extremity is the summit. The ventral margin is evenly but only slightly arched throughout to the end of the posterior process, in front it sweeps inwards almost at a right angle to form the antennal sinus; dorsal margin very boldly arched from the extremity of the rostrate process round the dorsal and posterior margins till it forms in the centre of that margin a blunt, conical termination; the rostral process is broad and widely rounded at the extremity, where it bends downwards; the antennal sinus is large and widely gaping. Surface of valves very uneven, sculptured with deep pittings, a ridge running parallel with the dorsal margin, and a large boss-like protuberance occupying the hinder portion of the valves, and in front of this are other irregular humps. The greatest height is equal to about three-fifths of the length, and the greatest width three-fourths of the height. Viewed from above, the form is irregularly oblong, the sides much undulated, in front the termination is very broad and of unusual length, the posterior extremity is linguiform, this portion of the outline being caused by the compressed extremity of the valves which lies beyond the boss-like protuberance. Length, 1·3 mm.; height, ·8 mm.

We have figured in Pl. LXII., figs. 20, 21, a fragment of a caudal lamina;

extremity imperfect, but showing a very peculiar unguis, which is slightly curved, ciliated, and bearing a small secondary spine on the convex margin.

A few specimens were dredged by the "Talisman" off the West Coast of Morocco in 1882 and 1883, in depths ranging from 836 mètres; and another specimen "off the Coasts of the Soudan," in 2333 mètres (Marquis de Folin).

## 2. *Streptoleberis rectirostris*, n. sp.

(Plate LIX., figs. 11–13.)

Shell in general form sub-quadrate, but less high behind than in front; greatest height anterior, while the greatest width is posterior; ventral margin strongly convex in front, and sweeping evenly to the bottom of the antennal sinus, behind only very slightly arcuate, and sloping gently upwards to the extremity of the posterior projection, which is slightly below the middle; dorsal margin passing from the extremity of the rostrate process, without arcuation, obliquely upwards and backwards to the point of greatest height, thence along the central dorsal portion it is straight, or even slightly concave, behind this it slopes suddenly downwards to the point where it meets the ventral margin, and forms with it the posterior sub-central blunt projection. The rostrate process is directed straight forwards, and is sub-triangular, of moderate length, and rounded at the extremity. It forms with the arcuate backward-sloping ventral margin a widely gaping, shallow antennal sinus. Valves very finely punctate, and furnished with a longitudinal acute ridge slightly below the centre, running backwards till it nearly reaches the posterior extremity; in front a branch runs downwards from this ridge to near the ventral margin, and then bending backwards it encircles that margin; opposite the origin of this ridge another runs obliquely upwards and backwards, and ultimately passing downwards loops with the first described ridge, and with it encloses a sub-triangular space, which is the most gibbous portion of the shell; in front of the ridges described, and just behind the sinus, a much narrower ridge traverses the valves vertically; at the hinder extremity, beyond the looping-ridge described above, the valves are suddenly and greatly depressed. The greatest height is three-fifths of the length, and slightly greater than the greatest width. Seen from above the form is slightly cuneiform, excessively wide behind, where it is suddenly truncate (the posterior extremity of the shell only slightly projecting in the centre of the truncate extremity); the sides thence converge without convexity, forwards, until slightly before the rostrum they more suddenly converge, and beyond this the rostrate process is seen protruded, with its length and breadth sub-equal. Length, 1.6 mm.; height, .9 mm.

A single specimen dredged by the "Talisman," August 11, 1883, off Arcachon in the Bay of Biscay in 2794 mètres; and another in 2333 mètres, off the coast of Soudan, July 15th, 1883 (Marquis de Folin).

Genus TETRAGONODON,\* n. g.

Shell of ♀ very tumid, without counting the extremities ovate; rostral process very long, projected almost directly forwards; greatest height of valves anterior; hinder extremity triangularly produced infero-posteally, slightly concave above. Antennules of ♀ six-jointed, third joint shortest; no sensory appendage. Antennæ with setæ short, not plumose; appendicular branch minute, consisting of a single joint terminated with a seta. Mandible with a masticating process cleft only at the extremity; no fixed spines on basal joint of palp, a small laminar appendage at extremity of that joint, unguis two, rather long. Second maxillæ with the three anterior lobes closely pressed together, ending in few setæ; upper tooth of great size, subquadrate, broadly truncate at the end, and smooth-edged; no lobe or setæ beyond the tooth, except those belonging to the three-lobed palp; vibratory plate well developed. Penultimate limb, as usual four-lobed. Caudal laminæ, with the unguis spined on the edge.

1. *Tetragonodon ctenorhynchus*, n. sp.

(Plate LVIII., figs. 1-8.)

General form of shell of female, ovate, excessively tumid, so that the breadth nearly equals the height; slightly concave on the upper part of the posterior margin, and with a long pointed, nearly erect rostrate process in front; greatest height equal to four-sevenths of the length, and situated just in front of the middle, from which point the outline declines gradually backwards; ventral margin from the bottom of the antennal sinus projected boldly outwards, and forming a very convex sweep for two-thirds of the length, behind this it gradually slopes upwards to the hinder extremity; the dorsal margin passes from the extremity of the prorected rostral process with moderately convex arcuation backwards to about one-half the length of the valve, behind this point the arcuation is only slight, until on reaching the commencement of the hinder margin, it sweeps down obliquely and with slight concavity to the point where it meets the ventral margin and with it forms a blunt angle at the infero-anteal corner. In front the rostral process is of remarkable length, and running out to a sharp point, is projected forwards, and only slightly downwards; beneath it the antennal sinus lies very widely open; the surface of the valves is everywhere pitted with little

\* τετράγωνος, square; ὀδών, a tooth.

round cells. Seen from above the form is widely ovate, the greatest breadth, which is central, being equal to more than half the length; the margins are boldly and evenly arched; in front the rostrate process is seen slightly projected, and furnished at the sides with four or five flattened nodulous processes; the posterior extremity is mucronate. Length, 2 mm.; height, 1.3 mm.

The antennules (fig. 3) have the proportionate length of the joints as is usual. Antennæ (fig. 4), with basal joint subquadrate, its length and breadth subequal, remarkably small and much shorter than the first joint of the swimming branch; first joint of the swimming branch slender, slightly arcuate and longer than the rest of the limb; setæ ten, short, ringed, but not plumose; a spine-formed seta on the basal joint of the antenna close by the origin of the appendicular branch, which consists of one short joint, and is naked and broad at the end, to one corner of which is attached a long terminal seta.

Mandible (fig. 5), with "masticating" process of basal joint long, and cleft only for a short distance at its extremity; first joint of palp without cleft spines, but furnished on the inner margin with six short, stout, ciliated setæ, and a longer seta on the central line between the more distant pairs of setæ just described, the upper margin having a seta towards the extremity, followed by a pair of setæ and a laminar appendage, which is about half the length of the following joint, and ends in two setæ; second joint with a pair of ringed setæ on the lower margin, preceded by a minute seta, all of these ciliated only on their central portion; third joint only slightly narrowing from the base to the extremity, bearing five ringed and ciliated setæ on the central portion of the upper margin, on the lower margin a single seta, and, then, near the extremity a pair of spines; last joint minute, with two short setæ and two long, gently curved ungues, which are crenated at the end.

The second maxillæ have the lobes very small and pressed close together, with very few setæ, apparently not more than four to any one lobe; tooth enormously developed (fig. 6), occupying by far the larger part of the end of the member, sub-quadrate in form, broadly truncate at the end, and smooth edged; no setæ beyond the tooth, except those belonging to the small palp, which consists as usual of three divisions, the first furnished with two, the second with four (?), the third with one (?) seta; vibratory lamina large, edged with about thirty-six setæ. Penultimate limb consisting, as usual, of four lobes, the first with three, the second with six, the third with five, the fourth with five setæ.

Vermiform limb with twelve spines, six of which are at the extremity; the spines are furnished with three or four pairs of spinules (fig. 7). Caudal laminae (fig. 8), rather narrow, bearing nine not crowded ungues, all strongly spined on the edge; in the smaller ungues the spines are only seen near the base, but in the larger throughout the greater part of their length.

The exact locality is unknown to us. The specimens were dredged by the "Talisman," July 11, 1883, in 932 mètres, and received by us from the Marquis de Folin; the date would lead us to suppose that *T. ctenorhynchus* was taken off the coast of Morocco.

The shell, in this species, is quite different in form from any other species which is as yet known; and very marked characters are present in the animal in the peculiar form of the appendicular branch of the antennæ; in the character of the "masticating" process of the mandible, in the remarkable large tooth of the second maxillæ, and the reduction in size of the other part of that limb; in the very rudimentary character of the vibratory lamina of the penultimate limbs, and in the spination of the ungues of the cauda, these ungues are sometimes ciliated, sometimes crenated, sometimes minutely denticulated, or serrated, but in no other case do we know them so strongly spined as in this species.

## 2. *Tetragonodon erinaceus*, n. sp.

(Plate LIX., figs. 14, 15.)

Shell, seen from the side, doubly bent, in general form ovate, with the anterior rostrate portion obliquely directed downwards, and the posterior sub-central triangular projection bent slightly upwards; ventral margin regularly and evenly arched throughout, in front penetrating at the antennal sinus to nearly half the entire height of the valves, thence the rostrate process is directed obliquely forwards and downwards to a remarkable length, with the extremity narrow; the antennal sinus is very widely open; the dorsal margin is anteriorly gently arched to the extremity of the rostrate process, centrally it is nearly straight, posteriorly the declination is sudden but well rounded; the posterior extremity is produced into a triangular compressed process, of which the upper side is nearly perpendicular to the hinder margin, while the lower is a portion of the continued sweep of the ventral margin. The total length is somewhat less than twice the greatest height, and the greatest breadth is equal to five-sixths of the height. The valves have a nearly perpendicular depression across them slightly behind the middle, and their entire surface, except the extremity of the posterior triangular projection, is covered with spinous processes, which for the most part are acute at their termination, but in some cases, especially on the hinder ventral portion of the valves, these spinous processes have clavate terminations. Viewed from above the form is ovate, the sides arched, the great anterior rostrate process projected in almost sub-quadrangular form, and the posterior triangular process appearing as a small rostrate projection. Length, 2 mm.; height, 1.1 mm.

Off Cape Blanco, coast of Morocco, "Talisman" Expedition (Marquis de Folin).

Genus 7. *PARAMEKODON*,\* n. g.

Shell in ♀ oval, excessively tumid, breadth sub-equal to height, antennal sinus a mere concavity, in front of which the rostrate process is projected directly forward; surface of valves in type species punctate and hispid. Antennules (Pl. LIX., fig. 3), six-jointed, without sensory organ on fourth joint, with terminal setæ sub-equal, two of them of remarkable character, flattened, membranous (fig. 3*a*), and closely waved in wrinkles; antennæ without any appendicular branch, in its place a large-ringed, plumose seta (fig. 4); mandible (fig. 5) with masticating process divided, but only at the extremity; no peculiar spines on the second joint, but the laminar appendage at its extremity well developed, limb ending in a single unguis of great length; first maxilla (fig. 6) short; second maxilla devoid of anterior lobes, teeth enormously developed, the upper (fig. 8) consisting of a great sub-oblong plate, with spiny processes on the margin, and terminating at the anterior extremity in a large fang, vibratory lamina well developed (fig. 7), external palp consisting of a single lobe; penultimate appendages without vibratory lamina (fig.) 9.

*Paramekodon inflatus*, n. sp.

(Pl. LIX., figs. 1–10.)

Shell of female regularly and broadly ovate, beyond which the rostrate process projects forward, and at the infero-posteal corner there is a slight lip-like protrusion of the valves; the antennal sinus is small, caused by the junction of the perfectly erect obtusely rounded rostral process with the natural and continued inward sweep of the ventral margin; ventral and dorsal margins very bold and evenly arched, the latter with a slight sign of angularity at its junction with the somewhat obliquely truncated upper portion of the posterior margin, the lower portion of which margin is slightly protruded, as already mentioned. Form excessively tumid, greatest height central, equal to five-sevenths of the length, and the breadth sub-equal to the height. Seen from above, the outline of form, except the extremities, is almost identical with the lateral view; greatest breadth central, sides very boldly and evenly arched, posterior extremity very broad; anterior, with the rostral portion much more compressed. Valves rather thin, surface very finely punctate, and sparingly hirsute.

Antennules (fig. 3) six-jointed, first joint longer than the combined length of two following joints; second and fourth joints sub-equal on the inner margin, the former the longer on the outer; third and fifth joints sub-equal, and each about half

\* παραμήκης, oblong; ὀδών, a tooth.

the length of the second; last joint minute: second, third, and fourth joints with one ringed and plumose seta on the upper margin, the second with two very minute spinules on lower margin, the third with one, and the fourth with two distal, long, ringed, and plumose setæ; penultimate joint with two minute setæ on the upper part of the extremity, and one long-ringed seta on the lower corner; last joint with five setæ of nearly equal length, two of which are of very remarkable structure, apparently membranaceous and flattened, being very closely and minutely wrinkled on every part, and (fig. 3 *a*) wholly destitute of cilia or other appendages. Antennæ with basal joint smaller than usual; swimming-branch nine-jointed, the last joint minute, with only two setæ, one of which is very small; nine setæ in all; no appendicular branch (fig. 4), but in the place usually occupied by it there is a very large-ringed plumose seta, near the origin of which are three very small, but distinctly ringed setæ.

The mandible has the basal joint furnished with a long masticating palp (fig. 5), cleft at the extremity for a short distance, and there hirsute; first joint of palp without masticating spines but with fascicles of very minute cilia on the side; inner margin with four setæ, two of which are small but ringed, the other large, ringed, and densely plumose, outer margin on the distal half with one long-ringed ciliated seta, followed by a pair of similar setæ, and at the extremity a well-developed laminar appendage, which is nearly two-thirds the length of the following joint, and ends in two setæ; second joint equal in length to about two-thirds of the first, with only one seta on inner, and none on outer margin; third joint more than half as long again as the second, inner margin with three series of minute cilia, followed by a spine, and then a pair of spines, outer margin with a fascicle of three or four setæ at the middle; last joint minute, bearing remarkably long and slender well-curved unguis, which exceed in length the two preceding joints, and below the unguis are two setæ.

First maxillæ (figs. 6, 6*a*) very short, with three lobes, the upper ending in three spines of remarkable character and a seta, the second in two spines and two setæ, the third is furnished with four setæ, the apical spines of the first two lobes have a spine-like process near the extremity of their outer side, the inner side in one case has the latter half very delicately serrated, in another case the lower half of the margin bears five or six spinules, and the distal half is finely ciliated; the distal margin of the lobe-bearing joint has a very large plumose seta below, a fascicle of three smaller setæ half-way up, and a large plumose seta above; the following joint has one seta on the upper margin, and one near the infero-posterior corner; the last joint bears a long slender unguis and three or four setæ.

In our dissection of the second maxillæ (fig. 7) we are unable to find any lobes or seta anterior to the teeth. There are two teeth. The outer of these (fig. 8) is of enormous size and consists of an irregularly oblong plate, or jaw, laid

horizontally. Beginning from behind, the upper margin of this plate throws out a vertical process divided into four teeth at the extremity; this is followed, after an interval, by another similar process divided into three teeth; after another interval another process with two teeth; and then the extremity rises into a great fang five or six times the length of the dentated processes which precede it. Below this tooth lies a second, in which on the further portion of the plate or jaw are some teeth which we cannot clearly see; but near the anterior extremity is a fang-shaped process, which has on its inner margin three denticulations; this is followed by the terminal fang, which is much smaller than that of the first jaw (not quite half its length), and instead of being a simple fang, as in that case, bears 3–6 denticulations in front and three nodulous processes on the side at the back. On the side of the first described jaw are two setæ placed close together. Beyond the jaws is the usual palp, which here is represented by a single lobe, with one lateral and four terminal setæ. Just behind the base of the palp are two small-ringed setæ; beyond these again comes the vibratory lamina, which has a somewhat flexuous outline, and is fringed with about forty-three plumose setæ. The penultimate appendages (fig. 9) consist of three lobes, the inner with one lateral and four apical setæ, the second with four apical setæ, the outermost with three apical setæ, and five large plumose setæ on its outer margin; the character of these setæ seem to suggest that they represent the coalesced vibratory lamina, which as a lamina is wholly absent.

The vermiform limb has six terminal and one pair of lateral, long, slender spines,\* with 3–5 pairs of spinules near the extremity; the tips of the end of the appendage itself are furnished with a few (we count four) simple, curved, spine-like processes. The caudal laminæ (fig. 10) are about twice as long as their breadth at the base; the ungues are ten, and being well separated at their origin occupy the greater part of the hinder margin; the third from the end is smaller than the fourth and second. The larger ungues are ciliated on the edge; the last is about the same size as the penultimate.

A single specimen was dredged by the "Talisman" off the coast of Morocco, July 6, 1883, in 1435 mètres (Marquis de Folin).

The single specimen which we have seen had been preserved dry. After drawing the shell it was macerated, and the animal being thus restored, has been dissected, figured, and described.

\* These curious processes we have in this work called spines, but they are not so here, and very often they are closely annulated in structure.

Fam. II.—RUTIDERMATIDÆ.

Shell oval, truncate behind, antennal sinus very shallow, no overhanging rostral process, surface of valves rugose. Antennules without sensory organ. Antennæ without any secondary branch. Mandibular palp, with last joints of great size, forming a large chela. No branchiæ.

Genus RUTIDERMA,\* n. g.

Shell oval, truncate behind, antennal sinus very small, no overhanging rostral process; surface of valves in type species rugose. Antennules (Pl. LVIII., fig. 12) without sensory appendage, a ringed seta taking its place. Antennæ (fig. 13) without any secondary branch. Palp of mandible (fig. 14), with last joint very massive, terminating in a strongly developed chela, formed by two very large processes, which are hooked at their extremities, the outer one flattened and pectinated on its inner face. Outer tooth of second maxillæ three-lobed, lobes plain-edged. Caudal laminæ (fig. 16) having few unguis.

The shell approaches in form to that of *Sarsiella*, but is oval instead of round, and the infero-posteal corner only slightly prominent; while anteriorly there is an antennal sinus of small size. The structure of the palp of the mandible is most remarkable. The account we give of the animal is derived from the maceration of specimens which have been preserved in a dried state for twelve years, many minute details, therefore, are wanting, and some of those given perhaps will prove to be not absolutely correct.

*Rutiderma compressa*, n. sp.

(Plate LVIII., figs. 9–16.)

General form of shell of ♀ oval, vertically truncated behind. Ventral margin well arched throughout to the infero-posteal angle; dorsal margin also boldly and evenly arched, but with very slight sinuses in two or three places, more especially just before reaching the supero-posteal corner; hinder extremity broadly truncated and bilobate, so as to leave a slight central sinus; anterior extremity rounded; antennal sinus very small and shallow, its upper margin forming a right angle with the bottom of the sinus, there being no vestige of a beak. Surface of valves very irregular, punctated with foveolæ

\* ῥυτίς, a wrinkle; δερμα, the skin.

all over, and sculptured with numerous riblets, two of these pass longitudinally round the ventral portion; another starting from the anterior extremity as its base gradually approaches the dorsal margin which it nearly meets at about two-thirds of its length; another longitudinal riblet is situated a little above the centre, and passes backwards till it approaches the hinder extremity, when it sweeps downwards and after forming two lobes unites with the ventral riblets; at the position of the two lobes just mentioned the valves attain their maximum obesity, and beyond this they are suddenly depressed to the flattened hinder extremity; a little in front of the middle of the shell there is a nodulous protuberance lying between the two uppermost riblets. Greatest height sub-central, equal to nearly three-fourths of the length; greatest width equal to only half the height. Seen from above the form is cuneate, abruptly truncated behind, with a slight central protuberance caused by the compressed hinder extremity, which juts out beyond the point of maximum breadth of the valves; from the truncation the sides converge forwards, at first only gently, but at two-thirds the length more suddenly, and meet at a slightly obtuse extremity in front. The end view shows that when the valves are broadest they are nearly equally so throughout their height. Length, 1.5 mm.; height, 1 mm.

Female(?) Frontal tentacle very long and slender. Antennules (fig. 12) five-jointed, geniculated at the end of the first joint, which is one-third longer than the second; second, third, and fourth joints sub-equal in length, last minute; the second joint bears one seta on the outer margin; the third one seta on each margin at its base, a seta at the end of the upper, and two rather long annulated setæ at the end of the lower margin; the fourth two minute setæ on the upper and a large annulated seta on the lower margin at the extremity; last joint with three large annulated setæ, and three of smaller size.

The antennæ (fig. 13) have the basal-joint pyriform, not so broad or large as usual, the length greater than the breadth; swimming-branch also rather more slender than usual, nine-jointed, the first joint long and slender, second to eighth, each with a swimming seta, last with five setæ, the furthest minute, and the next also short; appendicular branch altogether absent.

The palp of the mandible (fig. 14) is of very remarkable structure, consisting of only two joints and a chela; the mandible itself has a bifid masticating process. The first joint of palp has on the lower margin two masticating spines which are tuberculated on their edge, and two setæ, one of which is in front of and the other behind these spines; a third seta is borne at the end of the outer margin; second joint of immensely strong build, the outer margin very boldly arched, and bearing at its centre two small setæ, and one small seta at the inner-distal corner, otherwise the joint is naked; to its extremity is attached a very large and strong chela, the outer member of which is the shorter, falcate,

and smooth-edged, at its inner base are two long and two short spine-like processes, and further back two minute setæ; inner member also very strongly built, falcate, its lower margin, towards the extremity, bending slightly backwards, and then curving suddenly inwards, so as to form a hook-shaped apex, which closes over the end of the outer member, while its upper margin is flattened out to a knife-like serrated edge.

First maxillæ short, stout, and strong; first joint with two (or three?) lobes edged with spines, some of which are very strong, and denticulated on the edge, and others are serrated on one edge; second joint very short; third broader than long, boldly arched on the outer side, near the extremity of which is a single seta; last joint ending in a few short spines and setæ and two ungues, one of which is large and strongly denticulated on the edge.

Second maxilla with outer tooth large (fig. 15), very broad, and trifid distally, without any denticulated margin; number of setæ small, all we can see are about six inside the tooth, and two beyond it; palp, with central member ending in three setæ; vibratory lamina large, semicircular, fringed with about thirty-four long setæ. The foregoing must be regarded as an imperfect account of these maxillæ. Vermiform limb with about six spines at the end and four on the sides; the spines have about six pairs of spinules near the extremity. Caudal laminae (fig. 16) short, with only six ungues, of which the three uppermost are small and spine-like, the last three remarkably strong and blunt at their extremities, the last nearly twice as long as the penultimate and ciliated on the edge.

This species was found sparingly amongst the proceeds of two dredgings sent to us by M. de Folin; one of these was from off the Cap de Peñas (Bay of Biscay), the other from the Fosse de Cap Breton; depth, 150 mètres.

### Fam. III.—**SARSIELLIDÆ**,\* Brady and Norman.

Shell, round or oval in ♀, or obliquely truncate in ♂; strongly calcareous and the surface generally roughly sculptured, but sometimes nearly smooth; no antennal sinus in ♂, in ♂ sinus widely open and shallow; infero-posteally either simply rounded or more usually produced into a process of considerable size. Antennules (Pl. LX., fig. 8) five-jointed; antennæ ♀ (fig. 9) with appendicular branch scarcely developed, in ♂ small, but formed for grasping. Mandible (fig. 10) with basal joints of palp very stoutly built, penultimate joint very short, last joint terminating in a single claw. Second maxillæ (fig. 13) wholly devoid of tooth-processes; third

\* The whole of our MS. was written, and the plates prepared, before the publication of G. W. Müller's work. We have slightly modified the characters we had given of the family *Sarsiellidæ*, but for the rest have left the MS. as it was, retaining as a genus *Nematohanoma*, which G. W. Müller considers to be the male of *Sarsiella*.

maxillæ only represented by a single lobe, the vibratory appendage absent; vermiform limb (figs. 14, 15) of usual structure; caudal laminæ (fig. 17) with few unguis, rapidly increasing in length. No branchiæ.

\* No antennal sinus.

Shell round, with a largely developed conical extended process at the infero-posteal corner, . . . . . *Sarsiella*.

[Shell oval, infero-posteal corner rounded, a small projected point on the lower half of the anterior margin, *Eurypylus*.]

\*\* Antennal sinus shallow, widely open, shell obliquely quadrate, posterior margin very oblique, and infero-posteally much produced, . . . . . *Nematohamma*.

[Genus EURYPYLUS, G. S. Brady, 1869.]

“Les Fonds de la Mer,” vol. i., p. 141.

[Valvulæ testæ duræ, calcareæ, superficie dense foveolata, incisurâ nullâ; testa a latere visa rotundata, extremitate anticâ infra medium rostro brevi rotundato præditâ, posticâ rotundatâ; supra visa clavata, antice late rotundata, postice attenuata. Animal fere ignotum, antennæ superiores certe fasciculo setarum perbrevium armatæ.

***Eurypylus petrosus***, G. S. Brady, *l. c.*, p. 141, Pl. xviii., figs. 1, 2.

Testa a latere visa rotundata, altitudine maximâ  $\frac{3}{4}$  longitudinis circiter æquante in medio sitâ, extremitate posticâ rotundatâ, margine superiore leviter, inferiore valde convexo: supra visa clavata, latitudine maximâ dimidiâ longitudinis parte minore versus extremitatem anticam sitâ, lateribus postice convergentibus, extremitate anticâ rotundatâ in medio paulo mucronatâ, posticâ obtuse acuminatâ. Superficies valvularum foveolis rudibus sculpta. Long. 0.0008.

A single specimen from St. Vincent, Cape Verde Islands.

The palp of the mandible closely resembles that of *Sarsiella*; the last three joints are wholly devoid of setæ, the penultimate very short, about one-third the length of the preceding; the ante-penultimate joint is furnished, apically below, with an unguis, the penultimate with a longer unguis, the last with a still larger one; these unguis are gently curved, and in consequence of the shortness of the last joints their bases are close together. The caudal laminæ bear only four unguis; the distal one occupies the termination, and is of large size, and ciliated on the edge, the next is about half its length; the two upper are minute, and spine-like.]

Genus 1.—SARSIELLA, Norman, 1869.

(“Last Report Dredging, Shetland,” Brit. Assoc. Rep., 1868 (1869), p. 293.)

The female has the shell highly calcareous, usually roughly sculptured, sub-rotund, no antennal sinus, a produced process at the infero-posteal corner. Antennules five-jointed, second, third and fourth joints sub-equal, the fourth terminated by three long and several short setæ, but without a sensory appendage, a long annulated seta taking its place. Antennæ with the accessory appendage reduced to a nodule bearing a single short seta. Mandible without masticating process or masticating spines, the whole limb remarkably free from setæ; two terminal joints very short; each of these and also the preceding joint terminating in one strong curved unguis, the three unguis close together and increasing in length successively. The first maxillæ have four lateral setose lobes, the terminal joint is very short and broad, and at its extremity bears five stout spine-like setæ, which are ciliated on their edges, and spread out like the fingers of a hand. The second maxillæ bear three lobes and a one-jointed palp, all furnished with setæ but wholly without tooth-like organs or strong pectinated setæ; vibratory lamina well developed. Third maxillæ very small, consisting of a simple rounded lobe, setose at the edge; no vibratory lamina. Last vermiform limbs of the usual form. Caudal laminae with few (6–7) unguis.

This genus was established by A. M. N. in 1869, to receive a remarkable ostracod which he had dredged in the Shetland seas. Since that time four additional species have been described by G. S. B.,\* from the South Sea Islands, and we are now enabled to add a sixth from off the Soudanese Coast.†

1. *Sarsiella capsula*, Norman.

(Pl. LX., figs. 1–4, 18.)

1869. *Sarsiella capsula*, . . . NORMAN, “Last Report Dredging among the Shetland Isles,” Brit. Assoc. Rep., 1868, p. 293.  
 1887.     ,,     ,,     . . . Sars, G. O., “Nye Bidrag til Kundskaben om Middlehavets Invertebratfauna: iv. Ostracoda Mediterranea,” Archiv. for Mathem. og Naturvid., p. 57, pl. iii., figs. 5–7; pl. x., figs. 1–13.  
 1894.     ,,     ,,     . . . MÜLLER, G. W., “Die Ostracoden des Golfes von Neapel,” p. 214, pl. iv., figs. 4–6, 8–10, 22, 25, 27–29, 31, 33–35, 37, 48; pl. viii., figs. 6, 7.

\* G. S. Brady, “Ostracoda collected by H. B. Brady in the South Sea Islands.”—Trans. Roy. Soc. Edinburgh, vol. xxxv., 1890, pp. 516, 517.

† Since writing the above a seventh species, *S. laevis*, has been described by G. W. Müller.

Shell seen from the side nearly circular, the infero-posteal corner produced into a large conical process, ventral and dorsal margins nearly equally semicircular; anterior margin widely and regularly rounded, and circularly uniting with ventral and dorsal margins; surface very rugose, with concentric greatly elevated carina enclosing a deep hollow in the centre of the valve; from the exterior of the carina numerous radiating ribs pass on all sides to the margin; the interstices of these ribs and the central portion of the shell are sculptured with circular pittings. Seen from above, the form is very irregular, but upon the whole slightly cuneiform; greatest width posterior, at which extremity it is abruptly truncate and in the centre of the truncation the posterior conical process is seen projected; from the truncated end the sides converge gradually at first, and then more rapidly towards the anterior extremity, which is tolerably wide, and slightly emarginate in the middle. End view with concave sides, dorsally arched, and ventrally truncated. The valves are very much compressed in their centre. Length, 1.2 mm.; height, 1 mm. The male is unknown.

Antennules with second third and fourth joints sub-equal in length, the second joint with one seta on front margin, the third with two on the front, and three on hinder margin, the fourth with one long annulated seta which is not ciliated or filiferous, fifth joint with three long annulated setæ and some shorter setæ, at the distal extremity of hinder margin. Antennules bearing nine swimming setæ on the main branch, secondary branch rudimentary, consisting only of a little nodulous process carrying one short seta. Mandibular palp strongly unguiculate; mandible itself without any masticating process; first joint of palp without masticating spines or laminar appendage but with two or three small cilia on the hinder margin; second joint curved, broad and strong, the length not twice the breadth; fourth joint extremely short; each of the last three joints bearing a strong curved unguis, the three unguis being close together, and the distal longer than the preceding; the joints are wholly devoid of setæ, spines, or cilia. The first maxillæ (fig. 18) bear two or three lateral ciliated lobes, the penultimate joints bears a long spiniform ciliated seta on each side, and the last which is about three times as broad as long, has its extremity furnished with five short stout cuneiform spines, which are ciliated on the edges quite to the base, and spread like the fingers of a hand. The second maxillæ consist of a two-jointed member bearing at the extremity seven or eight setæ, but entirely devoid of teeth or other structures of allied character; a semicircular seta-edged vibratory lamina is present. Caudal laminæ with six unguis, which rapidly increase in length, the last being produced and greatly longer than the preceding.

*Habitat*.—St Magnus Bay, Shetland, 30–60 fathoms, 1867; off Valentia, Ireland, 1870 (A. M. N.).

*Distribution*.—Off Capri, Bay of Naples, 1887 (A. M. N.). Messina and Syracuse in 10–20 fathoms (G. O. Sars).

2. *Sarsiella globulus*, n. sp.

(Plate LX., figs. 5–17.)

Seen from the side the outline is circular, the height equal to the length exclusive of the posterior projection, which is longer and situated higher on the hinder margin than in the last species. The margins from above and below this projecting process form a complete circle round the ventral, anterior, and dorsal margins; the surface of the valves round the sides is more evenly convex than in *S. capsula*, but an oblique central portion is flattened and margined by riblets, the lower of which commences in front, a little within the anterior border and slightly below its centre; it thence passes downwards and then backwards towards the conical posterior process, at some distance from the base of which it suddenly bends upwards towards the dorsal margin, which it does not quite reach; the second riblet commences anteriorly a little above the first, and passes in an oblique direction across the valve towards the dorsal margin near which, and at no great distance from the termination of the previously described riblet, it ends in a blunt upraised point; the surface is everywhere punctated. Seen from below, the general form is oval, but towards the hinder extremity the outline becomes irregular owing to the prominence of the rib-bordered areas already described, while in the centre behind the posterior conical process is seen exserted. Greatest length, 2 mm.; height, 1.9 mm.

The antennules (fig. 8) resemble in every respect the same organs in *S. capsula*, except that the second joint has, besides the seta on the front margin, about three minute spinules, and one similar spinule on the hinder margin. The mandibular palp (fig. 10) has a much longer seta on the first joint in addition to the short spine-like setæ, and the terminal joint has a small secondary unguis in addition to the large unguis. The first maxillæ (fig. 11) have four lateral lobes, two of which bear six setæ, the third three, the fourth two; the extremity of the limb is armed as in *S. capsula*, but the terminal joint is rather longer. The second maxillæ (fig. 13) consist of three lobes and a single-jointed palp; the first lobe bears one, the second three, the last nine setæ; the palp ends in three setæ, and there is another seta on the limb at the base of the palp. The caudal laminæ (fig. 17) bear seven unguis, which are remarkably long and slender, and the last only proportionately longer than the preceding.

Off the coast of Soudan, North Africa, in 2333 mètres, "Talisman," July 15, 1883, a single specimen (Marquis de Folin).

## Genus 2. NEMATOHAMMA,\* n. g.

Shell of male obliquely subquadrate, hinder extremity very widely and very obliquely truncated, rostrate process not at all projected downwards, being abruptly truncated inferiorly; antennal sinus widely gaping; surface of valves rugose. Antennules bearing a nodiform appendage at the hinder extremity of antepenultimate joint, the appendage covered with a dense cluster of very long filaments, and also furnished with a long annulated seta. Antennæ with secondary appendage small, but formed for grasping. Mandible without any masticating lobe or peculiar spines at the base, third joint of palp very short, last joint carrying a single unguis. Copulatory appendages having terminal hooked processes.

Female unknown.

The curious dense cluster of very long filaments attached to a short clavate process on the antennules, and the structure of the mandibular foot, are the chief characters which separate the type of this genus from all other *Myodocopa*.

**Nematohamma obliqua**, n. sp.

(Plate LII., figs. 1, 2; Plate LIII., figs. 12–15.)

Shell of ♂ subquadrate, abruptly and very obliquely truncated behind; greatest height subcentral, equal to three-fifths of the length; ventral margin with only slight arcuation; dorsal margin highly convex centrally, but only gently arcuated towards the extremities; hinder margin abruptly widely and obliquely truncated, forming distinct angles at its junction with ventral and dorsal margins. The anterior extremity is bluntly rounded, without any sign of a beak, the lower side rising at right-angles from the bottom of the antennal sinus, which is shallow and completely open above, with its lower edge gently convex. Surface of valves very uneven, punctated, and furnished with many elevations and hollows; a strongly developed rib crosses the anterior extremity; the central portion of the shell is depressed, and surrounded by rib-like elevations, enclosing a subquadrangular space, which is wider behind than in front. The lower much elevated riblet which encloses this space is waved, being incurved in front, then boldly convex before it sweeps upwards at some distance from the hinder extremity to meet at a sharp and nodulated angle the riblet which bounds the enclosed space above; that riblet is arcuate, and runs at some little distance

\* νῆμα, a thread; ᾶμμα, a knot, *i. e.* a knot of filament in allusion to the appendage of the antennules.

within the dorsal margin; behind the enclosed space the shell is depressed, and a riblet passes from the infero-posteal corner to the surrounding riblet-wall of the enclosed space. Seen from above, the greatest width is behind the middle and equal to about two-fifths of the length: the form is narrowly-ovate, the anterior extremity wider at its termination than the posterior, which is projected in somewhat rostrate form beyond the part which is elevated and enclosed (on the side view) by the bounding riblets. Length, 1.25 mm.; height, 0.8 mm.

Antennules in ♂ (Pl. LIII., fig. 12), have the first and second joints sub-equal in length, the former without setæ, the latter with one annulated and ciliated seta on the middle of the front margin; third joint excessively short and rudimentary,\* fourth and fifth joints sub-equal, each rather shorter than the second; the former with one proximal and one distal seta on the front margin, a pair of long setæ on the middle of the hinder margin, and at its extremity a remarkable appendage, which is another form of the sensory organ of *Cypridina*. This sensory appendage consists of a short clavate process which is rather longer than wide and has its broadly-rounded extremity covered with a dense brush of filaments of such a length that they extend even beyond the terminal setæ of the limb; rising also from the distal side of the process, but so hidden by the mass of filaments that its base is difficult to detect, is a long annulated seta which stretches forward, side by side with the similar setæ of the last joints, sixth joint rudimentary; termination of limb with four or five long setæ, as well as others which are small.

The antennæ have the swimming-branch furnished with nine setæ, and its third joint only slightly shorter than the second; the secondary appendage (fig. 13) is small, but formed for grasping; its basal joint coalescent with the trunk, and indicated only by two minute setæ; the second (first free) joint is flexuous, about three times as long as broad, with two short spines,† last joint cylindrical, simple, blunt at the extremity, and reflected on the preceding joint.

Mandible (fig. 14) without masticating process or peculiar spines, basal joint very stout, first and second joints of palp curved, the former the longer, with three or four spinules on the inner margin, and near the extremity of the outer margin two small ringed setæ; second joint with a stout ringed and ciliated seta at the end of the inner margin; third joint with a single long ringed seta on each margin, last joint very minute, terminating in a single, long, gently curved unguis which nearly equals in length the last three joints, and bears a spine point half way down the outer margin; there are one or two minute spinules by the base of the

\* The limb, viewed from one side, appears to have such a joint, but on the other it is scarcely indicated.

† We call them spines, for they are spiniform; but they seem to have an annulated structure.

unguis.\* The copulating appendages (fig. 15) have each lobe terminating in a large hook-shaped claw; caudal laminae (fig. 15) with five rather long unguis, which gradually increase in length distally, the last, however, much longer than the penultimate; they are all strongly ciliated at the edge.

*Habitat*.—Dredged in 112 fathoms, off Valentia, Ireland, in 1870 (A. M. N.) Birterbuy Bay, Ireland, 1874 (A. M. N. and D. Robertson).

#### Fam.—HALOCYPRIDÆ.

Valves sub-equal, very thin and flexible, composed of two tunics, which are scarcely adherent except at the edges; hinge-margin straight, almost, or quite, edentulous; anterior extremity produced more or less into a beak-like prominence with a subjacent sinus. Eyes wanting, or present only in an abnormal condition. Projected forwards in the median line between the antennules is a frontal tentacle usually clubbed at the extremity.† Antennules dissimilar in the two sexes; in the female weak, indistinctly jointed, immobile and bearing a fascicle of sensory setæ; in the male larger, distinctly jointed, mobile, and with elongated setæ. Antennæ natatory and, as in Cypridinidæ, bearing a secondary branch, which in the male has a prehensile appendage. Mandibles well developed, biting plate dilated and toothed at the apex: palp large, four-jointed, geniculated, basal joint produced and forming a large chewing dentated lobe in contact with the biting apex of the mandible; terminal joints bearing curved setæ or spines. Two pairs of maxillæ. Two pairs of feet, the first pair the larger and dissimilar in the two sexes; second pair very small, both pairs having branchial laminae attached near the base. Caudal laminae short and clawed on the posterior margin. Copulatory organ of the male single, sinistral.

#### Sub-fam.—Conchœcinæ.

Shell elongated, its length usually very much greater than its height; rostral process well developed, and having a well-marked subjacent sinus. Frontal tentacles different in the two sexes; in the male surrounded by a tentacular circlet which springs from the second joint of the antennule, and ending in a club-shaped, angularly-bent capitulum. Peduncle of the antennules elongated and more massive in the male than in the female; in the female bearing one long, simple, terminal seta and four much shorter sensory filaments which are of equal length; in the

\* It will be observed on comparison of our figure and description of the limb, which stand as they were before Müller's work reached us, that they much more closely accord with the figure of this organ in his *Sarsiella lævis* ♂, than that of his *Sarsiella capsula* ♂.

† We employ the term "capitulum" for this clubbed extremity.

male there are three long, but unequal setæ, and two much shorter sensory filaments; the proximal seta much the longest, and armed in a part of its length with more or less numerous minute marginal spines or hooks. Secondary branch of the antenna bearing, on the basal joint a marginal, nipple-shaped prominence; natatory setæ scarcely longer than the peduncle, slightly dilated, and lancet-shaped towards their apices. Basal joint of the mandible palp elongated, and usually as long as, or longer than the united lengths of the three following joints. Second maxilla much shorter than the first foot which, in the male, is very large and ends in a lash of three equally long setæ.

Many species belonging to this sub-family we have had no opportunity of examining; in such cases we have simply given descriptions condensed from those of Professors Claus and G. O. Sars. We are, however, much indebted to both of those authors for their kindness in supplying us with examples of several of the species described by them.

Genus 1. *CONCHÆCIA*, Dana, ex. p.

Shell elongated, subquadrangular, posterior extremity truncated, sometimes smooth, but usually ornamented with a striated or reticulated sculpture either towards the margins or over the general surface of the shell; rostrum and sub-rostral sinus well developed; hinge processes absent or only feebly developed. "A group of club-shaped gland sacs near the posterior end of the dorsal margin, another group at the upper angle of the posterior margin of each valve, and a third at the infero-posteal angle of the right valve." Antennules of the female slender, cylindrical, bearing four sensory tubular filaments, and one long, slender seta, those of the male with three equal elongated setæ, and two unequal sensory filaments. Antennæ greatly developed, basal portion very large, pyriform, elongated, natatory branch 7-8-jointed, first joint elongated, the rest very short; secondary branch two-jointed, basal joint forming a flattened expansion, last joint short and bearing in the female a lash of filaments, and in the male an additional falcate process. Labrum hood-like, with irregular processes in front. Labium bilobed, inner margins of lobes setiferous. Basal joint of the mandible-palp as large as, or larger than the remainder of the limb (Plate xvi., fig 17) bearing at the apex a single stout plumose seta; last joint with three ciliated spines on the inner margin. First pair of maxillæ (fig. 18) composed of two masticatory lobes, with a large two-jointed palp which is armed with several curved spines. Second pair of maxillæ pediform (fig. 19) composed of a simple prehensile process, together with a three-jointed palp which terminates in three unequal curved claws. First pair of feet elongated, five-jointed; in the female directed downwards, apical portion like the palp of the second maxilla; in the male

much stronger, concealed within the valves, ending in three very long, and nearly equal curved setæ: in both sexes the basal joint bears a setiferous (branchial) lamina. Last pair of feet very small, two-jointed, reflexed, bearing two terminal setæ, one of which is very long, the other short. Caudal laminae short, rounded, posterior margin bearing a series of curved spines, and on the middle of the anterior margin a single long and slender curved spine. Copulative organ of the male oblong, with entire apex.

1. *Conchoecia elegans*, G. O. Sars.

(Pl. LX., fig. 23; Pl. LXV., figs. 11–22.)

1865. *Conchoecia elegans*, . . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 117.  
 1890. *Paraconchoecia gracilis*, . . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 15.  
 1891.       ,,       ,, . . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 66, pl. xii.

Shell of the female, seen laterally, elongated, sub-cuneiform, greatest height somewhat behind the middle and equal to less than half the length; rostrum large, and acutely pointed, with a subjacent, large, rectangular notch; dorsal margin straight, ventral moderately convex; posterior extremity much wider than the anterior, sub-truncate and almost rectangular, the lower angle rounded off. The valve of the right side is produced at the posterior dorsal angle into a short spine, which is armed on its upper margin with four small backward-pointing teeth. Seen from above the outline is narrow, ovate, greatest width behind the middle, obtuse in front, moderately pointed behind. Shell of the male somewhat more elongated, about thrice as long as high; rostrum sharper and more curved; posterior angle scarcely so prominent. Valves straw-coloured, marked with numerous closely-packed decussating striæ, the body of the animal showing through in deeply-coloured yellowish-brown patches.\* Antennules of the female small and weak; those of the male (fig. 12) much larger, the first two joints large and muscular, the last two extremely small and bearing setæ very unlike those of the female, one of them being very short, another elongated, very thick, obtuse, and turned backwards in opposition to the antennule, the remaining three setæ long, slender, and nearly equal in length. In the male beyond the middle of the

\* In spirit specimens, which alone we have had the opportunity of examining, the males are a deep-vinous or brownish-red, the females opaque, yellowish or tawny-white. Prof. G. O. Sars says, "fulvo-rubido pigmentatum."

external seta there is ranged on each margin a short series of extremely delicate cilia (Pl. LX., fig. 23); these are very flexible, and are set for the most part nearly at right angles to the stem, resembling somewhat the patch of loose plumes at the base of the vane of a feather; these cilia are so small and delicate that they are often seen with difficulty, even with a magnifying power of 400 diameters. The basal joint of the antennule shows, irregularly scattered near its surface, a number of lenticular bodies overlying patches of red pigment, perhaps rudimentary visual organs\* (Pl. LXV., fig. 12a.) Frontal tentacle in the female linear, in the male, dilated at the apex. Natatory branch of the antenna seven-jointed, the first joint more than twice as long as the remaining jointed portion; secondary branch bearing five apical setæ, of which in the female one is longer than the rest, while in the male (fig. 14), two are much elongated, one being thrice, the other four times as long as the shorter three; in addition to these setæ there is in the male a short sickle-shaped apical appendage. Male copulative organ (fig. 22) narrow, elongated, slightly dilated towards the apex, crossed by oblique transverse lines, and having an ejaculatory duct opening at its distal end. Length, 1.4 mm.

*Habitat*.—Taken abundantly by Dr. John Murray, in Loch Etive, Scotland, by the tow-net at a depth of 50 fathoms.

*Distribution*.—Rare in Drobak Fjord at a depth of 100–200 fathoms; very abundant among the Lofoten Islands down to 300 fathoms (G. O. Sars). This species is recorded by Dr. Claus (under the name of *Paraconchoecia gracilis*) as having been taken in a depth of 1500 metres, in lat. 37° 45' N., long. 13° 38' W.

## 2. *Conchoecia borealis*, G. O. Sars:

(Pl. LXI., figs. 9–19.)

1865. *Conchoecia borealis*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 119.

Shell of the female seen from the side, elongated, subquadrangular, higher behind than in front, greatest height equal to nearly half the length, dorsal margin straight, but showing a marked indentation near the middle, ventral slightly sinuated in the middle; anterior extremity gently convex, with a subacute rostrum of moderate size, and a slightly excavated sinus; posterior sub-truncate, rounded off below, and obtusely angulated above. Seen from above, elongate-ovate, about thrice as long as broad, widest near the middle, broadly rounded or sub-truncate in front, tapered and acutely-pointed behind. Surface of the valves densely cross-hatched with quadrangular reticulations (fig. 19) which are arranged

\* These are called "ganglia" by Dr. Claus, but if they are purely nerve-centres it is difficult to understand the meaning of the red pigment-masses associated with them.

diagonally, the edges of the areas overlapping each other in a squamous fashion; supero-posteal angle of each valve armed with three or four rather large marginal teeth. Shell of the male somewhat narrower than that of the female. Length 3 mm.

Capitulum of the frontal tentacle acutely-pointed at the apex, slightly hispid in the female (fig. 15), scarcely dilated at the base; in the male (fig. 13) dilated and rectangularly truncate. Antennules of the female (fig. 12) as in the preceding species, in the male (fig. 13) bearing three long setæ, the first of which is considerably longer than the other two, geniculated beyond the middle, and bearing along the median portion of its posterior margin a series of closely set, simple, recurved, spine-like cilia (fig. 14); there are also two short, sensory filaments, of which the posterior is recurved and very much convoluted. Caudal laminae (fig. 17), bearing on the anterior margin a single, long, slender spine, and on the posterior seven curved and finely pectinated spines, the posterior four much shorter than the rest.

Amongst the Lofoten Islands in a depth of 250–300 fathoms (G. O. Sars); Trondhjem Fiord, Norway, 150 fathoms (A. M. N.). Professor G. O. Sars remarks that he has found *C. borealis* only in one locality on the fishing bank of Lofoten, but that it was here tolerably abundant, and occurred in company with *C. elegans*, from which it was readily distinguished by its larger size, and by the form of the shell, notably by the sinuation of the ventral margin.

### 3. *Conchœcia maxima*, n. sp.

(Pl. LXI., figs. 1–8.)

Shell, seen from the side, subquadrangular, considerably higher behind than in front, greatest height scarcely equalling half the length; rostral prominence acutely pointed, with a rather deeply hollowed sinus beneath; anterior extremity well rounded away below, posterior truncated and widely rounded off below, obtusely angular above; dorsal margin almost straight, except for an abrupt depression near the middle; ventral very slightly arcuate; in the male the postero-dorsal angle of both valves bears a series of three teeth, the last of which is much thicker and larger than the others (fig. 1*a*). Seen from above, the outline is evenly ovate, about thrice as long as broad, extremities equal, sub-acute. The capitulum of the frontal tentacle (figs. 2, 3) is club-shaped, acutely pointed at the apex, and in the male dilated and truncated at the base; hispid with short, rather thickly set hairs. The stem of the antennule (fig. 2) shows, scattered through it in an irregular group, a number of dark red (? lenticular) bodies; and in the male the proximal long seta is armed throughout its middle third with a series of about

thirty closely-packed, short, recurved marginal spines (fig. 4). The secondary branch of the male antenna bears a thoroughly angulated, hooked appendage (fig. 5). Basal joint of the mandible palp not longer than the united lengths of the two following joints. Shell marked throughout with a not very conspicuous quadrangular reticulation (fig. 8). Spines of the caudal laminae like those of *C. elegans*, but having fine marginal pectinations. Length of the female 3·6 mm.; of the male 3·15 mm.

We are indebted to Dr. John Murray, F.R.S.E., for specimens of this species, which were taken abundantly off Greenland, in lat. 74° 49' N.; long. 11° 30' W., in a depth of 350 fathoms, and by H. M. S. "Triton," in 1882, lat. 60° 20' N.; long. 7° 23' W., in 200 fathoms, cold area, Faroe Channel.

Compared with *C. borealis*, which it very closely resembles, *C. maxima* is rather larger, and the shell is not so densely reticulated. The outline of the shell, seen dorsally, is different, and the spinules of the principal seta of the male antennule are considerably more robust.

#### 4. *Conchœcia magna*, Claus.

(Pl. LXII., figs. 5–13.)

1874. *Conchœcia magna*, . . . CLAUS, "Schriften zoologischen Inhalts: I. Die Familie der Halocypriden," p. 6, pl. i., fig. 6c; pl. ii., figs. 16, 18.
1887. ,, *tetragona*, . . . SARS, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," p. 82, pl. xi., figs. 5, 6; pl. xiii., figs. 5–9.
1890. ,, *magna*, . . . MÜLLER, G. W., "Ueber Halocypriden," Zoolog. Jahrbücher, vol. v., p. 274, pl. xxviii., figs. 28, 29, 33, 34, 39, 40.
1890. ,, ,, . . . CLAUS, Gattungen und Arten der mediterranen und atlantischen Halocypriden, p. 8.
1891. ,, ,, . . . CLAUS, "Die Halocypriden des atlantischen Oceans u. Mittelmeeres," p. 57, pl. ii., pl. iii., figs. 1, 2.

Shell of the female, seen from the side, oblong, subquadrangular, slightly higher behind than in front, the greatest height being equal to about half the length; dorsal margin nearly straight, ventral slightly sinuated in the middle; extremities very moderately rounded, postero-dorsal angle obtuse, not at all prominent;

rostrum wide, and moderately curved; sinus wide, and rather deep. The shell of the male is somewhat smaller and narrower, posterior margin almost rectangularly truncate, posterior dorsal angle prominent. Shell without any distinct sculpture, but very faintly marked with curved striæ. Length, 1.6 mm. (male); 1.8 mm. (female).

Capitulum of the frontal tentacle (fig. 6) in the male, destitute of hairs, rounded at its apex, curved and bent angularly on the stem; in the female (fig. 12) almost straight, slightly clubbed, but produced into a sharp point at the apex. Principal seta of the antennule of the male (fig. 7-7 a), bearing beyond the middle a patch of about twenty pairs of reflexed spinules, of which the proximal twelve are the longest, the distal seven or eight gradually decreasing in length to the last; the proximal sensory filament is about twice and a half as long as the distal one. Hooked appendage of the secondary branch of the right male antenna (fig. 8) angulated at the base, then bent abruptly, and forming a narrow arch; the three sensory filaments about half as long as the principal seta; in the female the principal setæ (fig. 13) are about one-fourth longer than the others; mamillary process of considerable size. Mandible-palp very stout, its proximal joint in the male scarcely so long as the three-jointed terminate portion, the first joint of which is as long or longer than the united lengths of the two following; terminal curved seta very strong, and bent in a subsigmoid fashion; the gland-vesicle extends through the three terminal joints: \* biting-plate of the mandible strongly toothed. Endopodite of the foot-jaw scarcely two-thirds as long as that of the first leg. The long anterior seta of the caudal lamina (fig. 10) reaches as far as the tip of the first marginal claw; the seven pairs of claws are stout and moderately distant, one from the other.

Procured by A. M. N., when at the Zoological Station, Naples, in 1887.

Dr. Claus states that this species is widely distributed both at the surface and in the depths of the Mediterranean and Atlantic.

Some of the anatomical details given above are borrowed from Professor Claus's description, our own specimens not having been sufficient to enable us to verify them in every point.

\* We have in no case been able to observe satisfactorily the curious glandular vesicles which are described minutely by Drs. Claus and Müller as existing beneath the shell and in other parts of the body of almost all the *Halocypridæ*. The prolonged preservation in alcohol of all our specimens has no doubt obliterated or obscured these organs.

5. *Conchœcia spinirostris*, Claus.

(Pl. LX., fig. 22.)

1874. *Conchœcia spinirostris*, . . CLAUS "Schriften zoologischen Inhalts. I. Heft., Die Familie des Halocypriden," p. 6, pl. i., figs. 1, 6a, 8; pl. ii., figs. 11, 14, 15.
1887. „ *pellucida*, . . SARS, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," p. 80, pl. xi., figs. 1-4; pl. xii.; pl. xiii., figs. 1-4.
1890. „ *spinirostris*, . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 7.
1891. „ „ . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 56, pl. i., figs. 1-12.
1894. „ „ . . MÜLLER, G. W., "Die Ostracoden des Golfes von Neapel," p. 237, pl. 6, figs. 1-9, 13.

Shell, seen laterally, oblong, pellucid, about twice as long as high; in the female, lower in front than at the feebly rounded hinder end; in the male, relatively higher, and with a straight posterior margin. Rostral sinus having a delicately serrated marginal membrane from which springs a fine bristle. Frontal tentacle of the female straight, slender, finely acuminate, that of the male angularly bent and clubbed at the capitulum. Principal seta of the male antennule scarcely longer than the adjacent ones, and having only eight or ten pairs of hooked marginal appendages (fig. 22) following which, but separated by wide intervals, are some hook-like processes of irregular size. The lower sensory filament is at least thrice as long as the upper. Hooked appendage of the secondary branch of the right male antenna strongly angulated. The five sensory filaments of the female antenna, with the exception of the very large principal seta, about equal in length. Proximal joint of the mandible-palp much elongated, longer than the three following joints. Ungues of the caudal laminæ curved only towards the points, and separated by considerable intervals from one another; the last four very small.

This species, according to Claus, is widely distributed at the surface in the Mediterranean, and has been taken also in the Adriatic at Trieste. The specimens described by G. O. Sars, under the specific name *pellucida*, were taken at Messina.

6. *Conchoecia striolata*, G. O. Sars.

1887. *Conchoecia striolata*, . . . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," p. 84, pl. xiv., figs. 1-5.

Shell of the male subventricose; seen from the side rather narrow, oblong, twice as long as broad, lowest in front; dorsal margin slightly depressed in the middle, ventral forming a continuous curve with the anterior extremity; posterior margin rectangularly truncate, its upper angle prominent; rostral process horizontal, sinus wide, and almost rectangular. Valves not pellucid; everywhere distinctly marked with decussating striae. Appendages almost exactly as in *C. magna*; unguis of the caudal laminae, however, stronger, and densely ciliated behind. Length, 2.36 mm. Female unknown.

Messina (G. O. Sars).

7. *Conchoecia Haddoni*, n. sp.

(Plate LXIV., figs. 6-16.)

Shell of the female elongated, subquadrate, not much higher behind than in front, height equal to considerably less than half the length; anterior margin moderately prominent below the rostral sinus, which is rather wide and shallow; beak stout and acuminate at extremity; ventral margin evenly curved; dorsal somewhat sinuous, and obscurely crenated towards the hinder end; posterior subtruncate, rounded off below, and subangular, but not spinous dorsally. Shell surface for the most part striated, the striae anastomosing irregularly at distant intervals (fig. 8), but within the antero-ventral, and, less distinctly, towards the postero-dorsal borders, closely reticulated with a small rhomboidal or pentagonal sculpture (fig. 7). Frontal tentacle of the female stout; capitulum (fig. 9) slightly curvate, slightly swollen at the base, and tapering to a narrowly rounded extremity, beset over the whole surface with short, distant, hair-like spinules; that of the male (fig. 10) similar, but very much more dilated at the base. The principal seta of the antennule in the male bears on its middle third a series of about thirty pairs (fig. 14) of very minute aculeate and reflexed spinules. Secondary branch of the antenna having a well developed narrow and subacute "mamillary" process, the distal prominence bearing two stout, short setae; in the female there are five setae, none of which are of the sensory kind, two of them long, the remaining three about half as long as the principal setae. In the male (fig. 15)

there are two long ordinary setæ and three short sensory filaments; the hooked process is on the right side, strongly falcate, bent almost at a right angle, and slightly bulbous at the apex, where on the inner margin there is a series of minute hair-like crenulations (fig. 15 *a*); the hook of the left side is not so strongly arched, nor is it much dilated at the apex. The labium consists of two cushion-like eminences, which are thickly clothed with long flexuous hairs. Biting plate of the mandible (figs. 12, 13) armed with four very stout dagger-shaped lateral teeth, and at its base with a dense growth of hairs, which, in the female, are for the most part blunt and truncated, as if broken or shorn off in the middle. The caudal laminæ (fig. 16) are short and broad, with rather stout unguis, which increase successively in length from the first to the last, and are finely, but very distinctly, pectinated on their concave margins. Length of the female, 3 mm.; of the male, 2.55 mm.

We have seen only three specimens of this species. These occurred in a tow-net gathering made by Professor Haddon at a depth of 200 fathoms, 40 miles off Achill Head, Ireland.

#### 8. *Conchoecia subarcuata*, Claus.

1890. *Conchoecia subarcuata*, . . . CLAUS, "Die Gattungen und Arten der mediterranean und atlantischen Halocypriden," p. 9.
1891. ,, ,, . . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 58, pl. iii., figs. 3-9, pl. iv.

Shell almost twice as long as high; length, 1.8-2.1 mm.; height, 1-1.2 mm. Like *C. magna*, but more elongated, and with a more strongly arched ventral border, and a more curved rostral process. Frontal tentacle of the male with a club-shaped, dilated, almost rectangularly bent capitulum; that of the female angularly bent, with a long, dilated apex, which is produced into a strongly hooked point, and is beset on the lower border with fine spines. The antennules of the male have the terminal seta armed with about thirty pairs of closely set hooked processes, which are shovel-shaped at their bases.

This species is, according to Professor Claus, very like *C. magna*, and was taken in a depth of 1500 mètres in lat. 37° 45' N.; long. 13° 38' W.; also in 500 mètres at Funchal, and at the surface of the Atlantic Ocean, on December 1st, 1887.

9. *Conchœcia bispinosa*, Claus.

1890. *Conchœcia bispinosa*, . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 10.
1891. „ „ . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 59, pl. v.; pl. vi., fig. 1; pl. viii., figs. 7, 8.

Shell elongated, twice as long as high, each valve with a short, strong, spinous prominence at the postero-dorsal angle; rostral process short and broad. Length of the shell, 1·5–1·8 mm.; height, 0·8–0·9 mm. Capitulum of the frontal tentacle in the female (as well as in the male) clubbed, angularly bent, and beset with numerous small spines. Terminal seta of the antennule in the male bearing about thirty pairs of closely set barbed hooks. Proximal sensory filament thrice as long as the distal one. Principal seta of the secondary branch of the natatory antenna, in the female, long and powerful, more than one-third longer than the longest of the sensory setæ. In the male the three sensory setæ are very slender; the hooked process is bent into an irregular curve, and on the left side is very strongly developed; one of the two lateral setæ much elongated.

Found at a depth of 1500 mètres in lat. 37° 45' N.; long. 13° 38' W.; also in surface-gatherings at Funchal (Prof. Claus).

10. *Conchœcia hyalophyllum*, Claus.

1890. *Conchœcia hyalophyllum*, . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 11.
1891. „ „ . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 60, pl. vi., figs. 2–10; pl. viii., fig. 9.

Shell rather short; height equal to about three-fifths of the length, nearly quadrangular, extremely thin and pellucid, much compressed laterally; rostrum large and curved. Length, 1·5 mm.; height, 0·9 mm.

Frontal tentacle of the female slender, elongated, with very long, angularly bent extremity, which bears on the upper margin a few spine-like hairs, and on the under side two rows of the same. Capitulum of the tentacle in the male shorter, broadly club-shaped, irregularly armed with spinous hairs. Terminal seta of the male antennule bearing about twenty pairs of slender, thickly-set spines, and not longer than the two neighbouring setæ; proximal sensory seta

thick and very long, almost as long as the antenna, in the female twice and a-half as long as the four sense-setæ. The principal seta of the secondary branch of the female antenna is scarcely longer than the longest of the four adjacent setæ. The hooked appendage of the right antenna of the male is bent to a right-angle at the base.

This species is recorded by Claus from Ischia at a depth of 900 mètres; from the Atlantic, lat.  $34^{\circ} 18' N.$ , long.  $15^{\circ} 34' W.$ , depth 1000 mètres, and from the surface of the sea at Orotava.

# 11. *Conchœcia porrecta*, Claus.

1890. *Conchœcia porrecta*, . . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 12.

1891. ,, ,, . . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 61, pl. vii.

Shell elongated, twice and a-half as long as high; dorsal margin incurved; posterior rather strongly convex; rostrum rather short; no spine at the postero-dorsal angle. Length, 1.6 mm.; height, 0.65 mm. Frontal tentacle of the female slender, straight and elongated, slightly dilated at the apex, and suddenly tapering to an acute point; in the male the capitulum is broadly clubbed, much stouter than the peduncle, and bent at an angle. Terminal seta of the male antennule armed with from forty to fifty pairs of hooklets, of which the fourteen or sixteen distal pairs are the stouter, and more closely packed; those towards the base being simple spine-like hairs, and set at wider intervals. Hooked appendage of the right antenna of the male bent at an oblique angle. Setæ of the secondary branch of the female antenna short and slender; the principal seta not much longer than the four sensory organs.

Numerous examples of both sexes were found by Dr. Claus in the Atlantic, from Cape Finisterre to Teneriffe, in depths varying from 1000 to 1600 metres.

# *Conchœcia obtusata*, G. O. Sars.

(Pl. LXIII., figs. 1, 2.)

1865. *Conchœcia obtusata*, . . . SARS, G. O., "Oversigt af Norges marine Ostracoder," p. 118.

1890. *Halocypris obtusata* . . . SARS, G. O., "Oversigt af Norges Crustaceer. II. Branchiopoda, Ostracoda, Cirripedia," p. 53.

Shell of the female seen from the side, elongate-ovate, equal in height before

and behind, greatest height somewhat less than half the length and situated in the middle; superior margin nearly straight; inferior moderately arcuate; posterior extremity obtusely rounded, prominent in the middle, obtusely angulated above, rounded off below; anterior extremity more than usually prominent below the rostrum, which is sub-acuminate and deflexed, antennal sinus narrow and directed forwards. Seen from above the outline is almost equally broad at both extremities, greatest width much less than the height, and equal to about one-third of the length, extremities obtusely acuminate. Valves delicately striated (Sars), but not reticulated; colour, pale yellowish. Frontal tentacle sub lanceolate, capitulum more dilated than that of *C. elegans*. Antennules as in *C. elegans*. Swimming branch of the antennæ eight-jointed, the last joint very small. Caudal laminæ small, like those of *C. elegans*, except that the seven claws gradually decrease in length backwards. Male unknown. Length of the female, 2 mm.

Very rare at the head of the Fekke Fiord, Norway, in rather shallow water; and in Trondhjem Fiord in 40–50 fathoms.

Professor Sars has kindly supplied us with a few specimens of this very scarce species, but not in a condition to allow of their being accurately figured or of the soft parts being fully made out. We have therefore transcribed his original description, giving only two outline figures drawn from the best preserved of our specimens. The second figure does not quite accurately agree with the description of Professor Sars, but this may perhaps arise from a slight gaping of the valves.

In a more recent work Sars has expressed the opinion that this species ought to be transferred to the genus *Halocypris*, a view which we are unable to adopt, as it seems to diverge in many important points from the character of that genus, as indicated by himself and Dr. Claus.

The shell is not very short nor rounded, nor is the rostrum particularly short or obsolescent as in *Halocypris*; the female antennules agree with those of *Conchæcia*; the basal parts of the antennæ and of the mandible-palps are as long as those of the similar organs in *Conchæcia*, and not very short as they ought to be in *Halocypris*. Lastly, a striking character given by Dr. Claus as belonging to *Halocypris* is here absent, namely, the lancet-shaped dilatation of the principal seta of the secondary branch of the antenna.

## Genus 2. PARACONCHÆCIA, Claus.

Shell scarcely different from that of *Conchæcia*, but very delicate, much compressed, and usually furnished with a spinous projection at the hinder end of the right valve; chewing portion of the mandible forming a triangular-toothed plate, which extends over the entire width of the limb, the four hooked teeth depressed towards the side, and enveloped in a more or less dense tuft of setæ.

**Paraconchœcia oblonga, Claus.**

1890. *Paraconchœcia oblonga*, . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 13.
1891.       ,,       ,,       . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 63, pl. viii., figs. 10, 11; pl. ix.

Shell elongated, with three or more teeth on the inner line of the anterior margin, and a spinous process at the postero-dorsal angle of the right valve. The shell of the male is twice, and of the female, twice and a-half as long as high. Length, 1·4–1·5 mm.; height, 0·6–0·7 mm. Frontal tentacle broadly clubbed at the extremity; in the female angulated, and pointed at the apex; in the male rounded at apex, terminal portion aculeated on the margin. Terminal seta of the male antennule much elongated, beset with numerous pairs of long, spine-like hairs; distal sensory seta rudimentary; in the female the terminal seta is likewise beset with spines, and is nearly double as long as the four sensory setæ. Hooked appendage of the secondary branch of the right male antenna sharply bent, but without any well-marked angle; in the female the principal seta of the secondary branch exceeds the four equal sense-organs by about half their length.

In lat. 37° 45' N., long. 13° 38' W., and lat. 34° 18' N., long. 15° 34' W., both at the surface and in the depths of the sea (Claus).

**Paraconchœcia spinifera, Claus.**

1890. *Paraconchœcia spinifera*, . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 14.
1891.       ,,       ,,       . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 64, pl. x.

Shell elongated, twice as long as high, very thin and delicate. Length, 1·8–2 mm.; height, 0·85–0·9 mm. The postero-dorsal angle of the right valve bears two spines, one smaller than the other. Frontal tentacle long and slender, its terminal portion short and stout, and beset with hairs on the ventral margin, the apex produced into a hooked point; in the male the tentacle is as in *P. oblonga*. Terminal seta of the male antennule armed with a very large number of spines. Hooked appendage of the secondary branch of the right antenna of the male bent to an acute angle near the base; in the female the four shorter setæ of the

secondary branch of the antennæ are of nearly equal length, and about two-thirds the length of the principal seta.

Dr. Claus records the occurrence of this species at Capri and in the Atlantic; lat.  $34^{\circ}$ ,  $18'$  N., long.  $15^{\circ}$   $34'$  W.

### Genus 3. *CONCHÆCETTA*, Claus.

Shell much elongated, in the female about thrice as long as high, hinder margin meeting the ventral obliquely, without sculpture, without hinge-teeth; glands of the dorsal margin wanting. Tooth ridges and chewing-edges of the mandible separate, both portions toothed on their free edges, the four hooked teeth largely developed.

#### 1. *Conchæcetta acuminata*, Claus.

1890. *Conchæcetta acuminata*, . CLAUD, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 16.  
 1891. ,, ,, . . CLAUD, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 67, pl. xiii. and pl. xiv.

Dorsal margin of the shell much longer than the ventral, and terminating in a spinous process, not always found on both valves. Rostrum in the female acutely pointed, in the male rounded off. Length of female,  $3\cdot2$ – $3\cdot4$  mm.; male,  $2\cdot3$ – $2\cdot4$  mm.; height of female,  $1\cdot2$  mm. Frontal tentacle of the female straight and elongated, very slender, acuminate at the apex; that of the male stout, bowed, and bent at a right angle. Antennules of the female (exclusive of setæ) reaching scarcely more than half the length of the tentacle; terminal seta beset with hairs, and almost three times as long as the four sub-equal adjacent setæ. In the male the antennules reach as far as to the bend of the tentacle, the terminal seta bearing twenty-four pairs of rectangularly bent, hook-like spinules, the two adjacent setæ about equally long.

In depths of 500 to 1000 mètres from the following Atlantic stations:—off Cape Finisterre, between Teneriffe and Grand Canary; and in lat.  $34^{\circ}$   $18'$  N., long.  $15^{\circ}$   $34'$  W.; also at the surface in the neighbourhood of Puerta Orotava.

### Genus 4. *CONCHÆCILLA*, Claus.

Shell much elongated, gaping, without hinge-processes, with a long, acute rostral prominence, and a long spine-like prolongation of the hinder extremity; surface marked more or less with diagonal ribs or reticulations; a patch of gland-cells near the ventral margin of the right valve; instead of the group of gland

cells at posterior angle of right valve there is a similar group near the front of its ventral margin; the dorsal gland-cells are wanting, but there are groups of such sacs (two on the right valve and three on the left), close to the posterior spinous extremity of the shell; abdomen conically elongated; armature of mandible as in *Conchœcia*, but with an unusually large transverse toothed ridge, and four long curved teeth.

The few specimens which we have seen, belonging to this genus, were in poor condition, and did not admit of our verifying some of the characters ascribed to it by Dr. Claus, more particularly those relating to the gland cells, which we have not seen. But the very characteristic and remarkably formed shell is of itself sufficient to constitute a good generic feature.

### 1. *Conchœcilla daphnoides*, Claus.

(Pl. LXIV., fig. 22.)

1890. *Conchœcilla daphnoides*, . CLAUD, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 18.  
 1891. ,, ,, . . CLAUD, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 68, pl. xv.

Shell almost flat dorsally, much elongated, height very small, but valves outstretched and almost wing-like; ventral margin arched, bending upwards behind, and meeting the dorsum at an acute angle; anterior margin narrow, convex, and forming a sharply angular sinus at its junction with the long rostrum, which is longer on the left valve than the right; each valve bears at the long, pointed, posterior extremity a series of marginal spinules, the right valve being a good deal the longer of the two. Length, 2·85 mm.

We found a single specimen of this species amongst material taken by Professor Haddon in the deep tow-net (200 fathoms) 40 miles off Achill Head, Ireland. This specimen we have here figured, but our descriptive details are taken from Dr. Claus's monograph.

*Distribution*.—Young specimens were taken by Claus in lat. 37° 45' N., long 13° 38' W., and in lat. 34° 18' N., long. 15° 34' W.

### 2.—*Conchœcilla lacerta*, nov. sp.

(Pl. LXII. fig. 1–4; LXV., fig. 1–10.)

Shell, seen from the side, much compressed and greatly elongated; greatest height situated in the middle, and equal to one-fifth of the length; anterior

extremity produced into a very long, slightly curved, slender, acutely pointed rostrum, at the base of which is a distinct, though shallow sinus, which passes at a right angle into the narrow anterior margin; the posterior extremity is formed by a long spine-like projection, which is wide at the base, and acutely pointed behind, rectilinear above and continuous with the dorsal margin below, passing by a gentle curve into the ventral margin; dorsal margin slightly curved towards the front, having a distinct median indentation, but otherwise almost straight; ventral gently and evenly arcuate as far as its juncture with the posterior spine; margins of the valves entire, except round the produced posterior extremity, which is armed, especially on its ventral edge, with numerous adpressed, backward-pointing spines. Surface of the shell marked, chiefly toward the hinder extremity, with faint decussating striæ, which form a scale-like reticulation. Seen from above, the outline is much compressed, width and height about equal, produced in a cuneate fashion in front, and into a long attenuated spine behind. The antennule bears in the female (Pl. LXV., fig. 5) one long terminal seta, and four very short sub-equal sensory filaments; in the male (Pl. LXII., fig. 1), are three long setæ, the proximal one being much longer than the rest; two very short, straight filaments, and a third, which is hook-like and curved backwards; the long, proximal seta is beset from the middle nearly as far as the base, with a series of very fine, closely packed, recurved hairs (Pl. LXII., fig. 2). Frontal tentacle in the female very slightly clubbed, a little hispid, its tip slightly produced and pointed; in the male the capitulum is curved, blunt, and slightly bulbous at the apex, dilated and truncated at the base. The basal joint of the secondary branch of the antenna in the male (Pl. LXII., fig. 3) has an angularly-bent hook. Basal joint of the mandible-palp (Pl. LXV., fig. 7) about equal in length to the three following joints. Apical setæ of the first foot (Pl. LXV., fig. 8) in the female nearly equal: the last foot (Pl. LXV., fig. 10) has one very long seta, and another about half as long. Length, 4.73 mm.

Of this remarkable species we have seen only two or three specimens, which were taken by Dr. John Murray, in H. M. S. "Triton," in 1882, lat. 60° 31' N.; long. 7° 34' W., in 580 fathoms; and in lat. 60° 20' N., long. 7° 55' W., in 200 fathoms, these stations being in the cold area east of the Faroe ridge in 200 fathoms, August 20, 1882. The size of the specimen and their general configuration lead to the suspicion that they may, perhaps, belong to the adult form of *C. daphnoides*, of which species no fully grown specimens have (as Dr. Claus thinks), yet been seen. But without further evidence we should scarcely be justified in uniting the two forms under one specific name.

Genus 5. *Conchœcissa*, Claus.

Rostral process beak-like, long, sharp and strongly curved; sinus moderately large; hinder extremity of each valve produced dorsally into a backward-pointing sharp spine, and ventrally into a rounded or obtusely-pointed spine. Shell distinctly striated, and towards the free margins strongly reticulated; ventral margin more or less roughened with minute projecting spines; mandible with well-developed tooth-ridges and four large lancet-shaped spines.

1. *CONCHÆCISSA*, *armata*, Claus.

(Pl. LXIV., figs. 1–5.)

1890. *Conchœcissa armata*, . . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 19  
 1891. ,, ,, . . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 70, pls. xvi., xvii., xviii.

Shell elongated, lower in front than behind, greatest height equal to less than half the length; seen from the side the outline is sub-quadrate, rectangularly truncate behind, ventral margin rather protuberant; striation of the shell well marked, the ventral and anterior portions strongly reticulated with transverse rows of elongated sub-quadrate areas, which towards the postero-dorsal angle become nearly square, and in the central area almost give place to the longitudinal striæ. Rostrate process large, very acute at the apex, at first directed straight forwards, afterwards slightly curved downwards; lower margin of the antennal sinus well arched forwards, leaving a slight hollow at its junction with the base of the rostrum. Infero-posteal corner produced into a conspicuous acute spine-shaped process, that of the right valve being longer than that of the left; infero-posteal corner also produced into a blunt, spine-shaped process, which, however, is not so large as the dorsal spine. The lower border of this process is represented by Claus as serrated, but it is not so in our specimen. The chief peculiarity of this structure is that it is not a production of the edge of the valve, but takes its origin at some distance within the border (Pl. LXIV., fig. 1). Frontal tentacle of the female (fig. 3), much longer than the antennule, capitulum slender, only slightly club-shaped, and having a few small marginal spinules; in the male the organ is much shorter, the capitulum distinctly clubbed, and bent at a right angle to the peduncle. The principal seta of the antennule of the male bears eight or nine pairs of unusually strong hooklets. The setæ and

sensory filaments of the secondary branch of the antennæ are very long, and the mamillary prominence is large and tooth-like; in the male the prehensile hook of the right side is rectangularly bent at the base, and curved beyond; on the left side simply hooked; the mamillary process slightly hooked. Teeth and general armature of the mandibles (figs. 4, 5) strongly developed. The long posterior seta of the caudal lamina is pectinated with short, fine cilia; the seven marginal unguis increase progressively in length from the first to the last, and are smooth and somewhat widened at the base, pectinate beyond. Length of the shell 3 mm. (female).

Tow-net, "Triton" Expedition, lat. 60° 20' N., long. 7° 53' W., in 200 fathoms, 20th August, 1882, in the cold area of the Faroe channel (Dr. J. Murray). In a depth of 1000 mètres, lat. 34° 18' N.; long. 15° 34' W.; 500 mètres, lat. 32° 30' N.; long. 16° 42' W. (Claus).

Dr. Claus doubtfully identifies this species with *Halocypris imbricata* of the "Challenger" Ostracoda Report, but a comparison of specimens (females only), scarcely bears out this opinion, though the resemblance is certainly very close.\* The mandibular teeth of the two forms seem to be slightly different, and the natatory antennal setæ of *H. imbricata* are very conspicuously plumose, while in *C. armata* they are quite simple. The size of *C. imbricata*, also, is greater, being 3.6 mm. for the female, and 4 mm. for the male.

The foregoing description, so far as the male is concerned, is taken from Dr. Claus; the only specimen which we have seen is a female.

#### Genus 6. MIKROCONCHÆCIA, Claus.

Shell compressed, of small size, and with a striated or reticulated sculpture of the outer surface; anterior margin prominent, dorsal margin without any posterior projection. Hinge well developed, a tooth on the left, and a hollow on the right valve. The hooked lateral teeth of the mandible are strengthened by a strong chitinous plate (Claus), and there is a marginal bearded line of cilia and short bristles. Proximal sensory filaments of the antennæ of the male furcate; in the female, most, if not all of them, are once or twice forked.\*

#### **Mikroconchœcia Clausii**, G. O. Sars.

(Pl. LXIII., figs. 3–9.)

1865. *Halocypris* sp., . . . CLAUS, "Ueber die Geschlechts differenzen von *Halocypris*," Zeitschrift für Wissensch. Zoologie, Bd. xv., Taf. xxx. (*vide* Claus).

\* Claus says that all except one are furcate, but we have not made this out clearly.

1887. *Halocypris Clausii*, . . Sars, G. O., "Nye Bidrag til Kundskaben om Middelhavets Invertebratfauna: iv. Ostracoda Mediterranea," p. 87, pl. xi., figs. 7-10; pl. xiv., figs. 6-18.
1890. ,, ,, . . Claus, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 22.
1891. ,, ,, . . Claus, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 73, pl. xx.
1894. *Conchæcia Clausii*, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel," p. 230, pl. vi., figs. 21, 23-30; pl. viii., figs. 31, 32.

Shell of the female, seen laterally, broadly sub-ovate, very short and high; length not much greater than the height; dorsal margin almost straight, ventral evenly, and boldly convex, and forming a continuous curve with the anterior and posterior margins; rostrum rather large, curved and prominent; sinus of moderate size; anterior extremity curved, rather prominently arched below the sinus, slightly narrower than the posterior, which is sub-truncate, very boldly rounded at its junction with the ventral margin and not at all produced at the obtuse dorsal angle. Seen from above, the outline is broadly ovate, widest behind the middle; width considerably more than half the length. Shell of the male rather narrower; seen from above, widest towards the front (Sars). Surface of the valves strongly reticulated. Length of the female .78 mm.; of the male .72 mm. Frontal tentacle of the female (fig. 7) not reaching beyond the extremity of the limb, nearly straight, capitulum obtuse; that of the male much longer than the limb; capitulum curved, spoon-like, dilated at the base. Antennules of the female small, imperfectly jointed, the sensory setæ sub-equal, furcate; antennules of the male (fig. 5) five-jointed, the two basal joints very stout, the rest very small; the proximal sensory filament is about as long as the second joint of the antennule and furcate; the distal filament simple and about half as long as the other; of the three long setæ the distal one bears on its inner margin a series of (seven to fourteen, Claus), small button-like nodules (fig. 6) which are set in a single row and wide apart. Hooked appendage of the antennæ (fig. 8), strongly bent and thickened towards the base. The male copulatory organ (fig. 9) has the distal half of its posterior margin annulated. The other organs present no special diagnostic characters.

Capri; Las Palmas, 450 mètres; Funchal, 500 mètres (Claus); Messina (G. O. Sars); Naples (A. M. N., and G. W. Müller).

Sub-fam.—**Halocyprinæ.**

Shell short, ventricose, scarcely longer than high; rostral process short, sinus obsolete, presenting only a slight sinuation of the valve. Frontal tentacles alike in both sexes; capitulum club-shaped, bent at an obtuse angle on the peduncle. Peduncle of the antennule angularly bent, setæ flexuous; in both sexes one long terminal seta, and four short equal sensory ones. Secondary branch of antenna without mamilliform prominences; setæ of the swimming branch plumose, and nearly twice as long as the peduncle. Basal joint of the mandible-palp short, not longer than the second joint, its biting-plate produced, and "shovelshaped." First and second pairs of maxillæ short, and nearly equal. In the male the first maxilla is like that of the female both in size and shape, and the terminal setæ do not form an elongated lash.

Genus 1. **HALOCYPRIS**, Dana (*ex parte*).

Rostral process short, right valve prominent in front; rostral sinus inconspicuous; ventral margin strongly convex; a hinge-joint, consisting of a tooth on the left and socket on the right valve at the anterior extremity; hinge of hinder end scarcely developed. Free edge of the valves strongly rounded and thickly beset with gland-cells. Principal seta of the secondary branch of the antenna dilated and lancet-shaped at the end. Mandible without a crenulated pad and accessory teeth, but having a broad conical process directed towards the apex of the limb.

1. **Halocypris concha**, Claus.

(Pl. LXII., figs. 14–19.)

1874. *Halocypris concha*, . . . CLAUS "Schriften zoologischen Inhalts: 1. Die Familie der Halocypriden," pl. ii., figs. 20–25; pl. iii., figs. 26–35.
1890.     "         "         . . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 24.
1891.     "         "         . . . CLAUS, "Die Halocypriden des atlantischen Oceans und Mittelmeeres," p. 77, pl. viii., fig. 12; pl. xi., figs. 6, 7; pl. xxii., figs. 1–12; pl. xxiv., figs. 6–20; pl. xxvi., fig. 1.
1890.     "         *dubia*, . . . MÜLLER, G. W., "Ueber Halocypriden," Zoologischen Jahrbüchern, vol. v., p. 269, pl. xxviii., figs. 19, 23, 24, 30, 35: var. *major*.

Shell marked with delicate, more or less distinct concentric lines, which are here and there arranged crosswise. Length about 1·8 mm.; height, 1·4 mm.

Capitulum of the frontal tentacle long (fig. 15), subsigmoid in shape. Terminal seta of the antennule nearly twice as long as the four sensory filaments. Basal joint of the main branch of the antenna about twice and a-half as long as the apical, short-jointed portion, which is provided with very long plumose swimming setæ; principal seta of the secondary branch dilated and fusiform towards the apex, only slightly longer than the neighbouring seta, which is about twice as long as the remaining three equal setæ. Hook of the secondary branch of the left male antenna (fig. 16) broadly curved. Of the three terminal setæ belonging to the first and second maxillæ, two are curved, and nearly equal in length, the third shorter and more slender. Marginal spines of the caudal laminæ (fig. 19) elongated, slender, and slightly curved.

A few specimens occurred in tow-net gatherings taken by the "Challenger" expedition, but were not recognized nor described by Dr. Brady in his Monograph of the Ostracoda. These were from the following stations:—Lat. 35° 18' N.; long. 147° 9' E.\*; and lat. 32° 41' N.; long. 36° 6' W.; lat. 35° 41' N.; long. 157° 41' E. Dr. Claus gives "Atlantic Ocean" merely as the habitat of this species, and Dr. G. W. Müller does not seem to be any more precise in his record.

Though we do not doubt the identity of our specimens with *Halocypris concha*, Claus, it should be noted, that the reticulated ornament of the shell is somewhat more pronounced than that described by Dr. Claus. Owing to paucity of material we have had to adopt, for the most part, Dr. Claus's description of the species.

## 2. *Halocypris pelagica*, Claus.

1890. *Halocypris pelagica*, . . CLAUS, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," p. 25.

1890. „ *dubia*, . . MÜLLER, G. W., "Ueber Halocypriden," Zoologischen Jahrbüchern, vol. v., p. 269, pl. xxviii., figs. 19, 23, 24, 30, 35; var. *minor* (*fide* Claus).

1891. „ „ . . CLAUS, "Die Halocypriden des atlant. Oceans und Mittelmeeres," p. 78, pl. xxi., figs. 1–11.

Length of shell, 1·1–1·4 mm.; height, 0·9–1·1 mm. Frontal tentacle proportionately thicker and shorter than in the preceding species, capitulum

\* It should be mentioned that the inscribed date on this gathering has become partially illegible, and the locality may therefore be erroneous.

shorter, and scarcely bent. Antennules more strongly curved, twice bent in a rectangular manner; terminal seta nearly twice as long as the four sensory setæ. Peduncle of the natatory branch of the antenna about twice as long as the short-jointed distal portion, which bears long plumose setæ: principal seta of the secondary branch greatly dilated, and about one-third longer than the next seta, which is again double the length of the remaining three; hooked appendage of the male bent upon itself abruptly at the base.

Taken at the surface, and in various depths, as follows:—Off Cape Finisterre, in lat.  $37^{\circ} 45' N.$ , long.  $13^{\circ} 38' W.$ ; lat.  $34^{\circ} 18' N.$ ; long.  $15^{\circ} 34' W.$ ; lat.  $32^{\circ} 30' N.$ ; long.  $16^{\circ} 42' W.$ ; off Funchal (Claus).

#### Genus 4. *Halocypria*, Claus.

Shell almost globular, with small but distinct rostrum, and deep sinus. Hinge at hinder end well-developed. Principal seta of secondary branch of antenna very long, filiform, not dilated nor lancet-shaped. Mandible bearing, in addition to the transverse rows of teeth, a group of four strong curved teeth near the base. First pair of legs short and stout, almost conically pointed.

The characters which, according to Claus, chiefly distinguish the shell of this from the preceding genus are the larger development of the posterior hinge-processes, the more pronounced rostrum and deeper sinus, together with the presence, on the anterior border of the right valve, of a considerable prominence, and on the left valve two smaller prominences.

##### 1. *Halocypria globosa*, Claus.

1890. *Halocypria globosa*, . . CLAUS, "Die Gattungun und Arten der mediter-  
ranen und atlantischen Halocypriden," p. 25.  
1890.       "       "       . . MÜLLER, G. W., "Ueber Halocypriden," Zoolo-  
gischen Jahrbüchern, vol. v., p. 270, pl.  
xxviii., fig. 20.  
1891.       "       "       . . CLAUS, "Die Halocypriden des atlantischen  
Oceans und Mittelmeeres," p. 79, pl. xxii.,  
figs. 13–18.

Shell almost spherical, with delicate longitudinal striations on the dorsal surface; hingement consisting of a tooth and fossa strongly developed at the hinder end. Frontal tentacle elongated, with a long deflexed capitulum

Peduncle of the principal branch of the antenna twice and a-half as long as the short-jointed apical portion, which has plumose swimming setæ, setæ more than half as long again as the limb itself, the principal seta of the secondary branch is more than twice as long as the sensory filaments. Caudal laminae bearing seven pairs of curved spines. Length, 2.2 mm.; height, 1.8 mm.; width, 1.6 mm.

Atlantic Ocean; taken at the surface, and in various depths (Claus); Gibraltar (Chierchia, *vide* G. W. Müller).

A single specimen was noticed amongst the "Challenger" captures, but the exact locality is doubtful. The male of this species has not yet been seen.

Our description is taken in part from that given by Dr. Claus; the one specimen which we have had the opportunity of examining being imperfect.

### SECTION III.—Cladocopa, G. O. Sars, 1865.

#### Fam.—POLYCOPEIDÆ, G. O. Sars.

Shell round, or nearly so, valves thin, sub-equal, without the antennal sinus usually found in Myodocopa. Antennules and antennæ adapted for swimming, both with large muscular basal joints, and long terminal setæ; the former not branched nor geniculated; the latter biramose, both branches natatory. Mandibles distinctly toothed, furnished with a palp, which is not pediform, ending in setæ, not in ungues. Only two pair of limbs behind the mandible, and these formed for swimming, the first with one very minute seta-bearing lobe on the basal joint, and a long laminar appendage attached to the antepenultimate joint; the second of these limbs is much smaller than the first, its three-jointed basal joint wide and expanded on one side into a seta-edged branchial plate. Caudal laminae broad and rather short, their hinder margin bearing a series of ungues. No eyes. No heart. Intestine forming a simple sac.

#### Genus POLYCOPE, G. O. Sars, 1868.

Shell nearly round, texture thin and fragile, corneous, and only slightly calcareous. No frontal tentacle, but in its place two short ciliated setæ. Antennules (Pl. LXVII., fig. 1) three-jointed, terminating in very long setæ. Antennæ (Pl. LXVII., fig. 2) with the branches sub-equal in length, the larger branch similar in structure to the natatory branch in Cypridinidæ, nine-jointed, and bearing lateral and terminal swimming setæ, the other branch three-jointed ending in a bunch of setæ. Mandible (Pl. LV., fig. 13) with a masticating toothed lobe, palp two-jointed, the first joint strong, and furnished above with a small

seta-tipped laminar appendage, second joint with lateral and terminal setæ. Incisive portion of the first maxilla (Pl. LXVII., fig. 3) forming a small unguiferous and setiferous lobe, and bearing a very large four-jointed palp, from the second joint of which springs a large laminar appendage, which together with the palp itself is densely setiferous at the apex. Second maxilla (Pl. LV., figs. 14, 15) three-jointed, first two joints very massive, last slender, and giving origin to a single stout apical seta; to the basal joint is attached a semi-elliptic, seta-edged branchial plate. Caudal laminae (Pl. LV., fig. 16) having the ungues set in deep incisions of the margin, which is projected between the bases of the ungues in conspicuous processes.

***Polycope orbicularis*, G. O. Sars.**

(Pl. LIV., figs. 9, 10; Pl. LV., figs. 12–16; Pl. LXVII., figs. 1–3.)

1865. *Polycope orbicularis*, . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 122.  
 1868.     ,,           ,,       . . . Brady, "Monog. Recent Brit. Ostr.," p. 471, pl. xxxv., figs. 53–57.  
 1874.     ,,           ,,       . . . Brady, Crosskey, and Robertson, "Monog Post-Tertiary Ostracoda," p. 219, pl. xii., figs. 22, 23.

Shell of the female, seen from the side almost circular, greatest height situated in the middle, and nearly equal to the length, posterior extremity well rounded, anterior narrower, and slightly exserted, dorsal margin strongly arched, almost angulated in the middle, ventral evenly and rather boldly arched; seen from above the outline is broadly sub-rhomboidal, widest in the middle, the width equal to considerably more than half the length, extremities equal and obtuse. Surface of the valves covered with closely-set small circular impressed puncta, and marked with a polygonal reticulated pattern, the ventral margin fringed with small sharp spines or setæ. Colour yellowish, mottled with reddish spots or patches.

Antennules (Pl. LXVII., fig. 1), three-jointed, basal joint very massive, pyriform, front margin finely ciliated, and bearing one small seta, second and third joints small, especially the last, the penultimate with one small terminal seta, the last having five setæ, which exceed in length the whole limb. Antennæ (Pl. LXVII., fig. 2) with the basal joint very broad and massive, chief natatory branch nine-jointed, basal joint without seta, shorter than combined length of following joints, remaining joints broader than long, joints 2–8 each with one long natatory

seta, last joint with two somewhat shorter terminal setæ; the second branch has the first joint naked, much surpassing the length of the two remaining joints, which are very short, and furnished with a terminal bunch of long setæ. The mandible (Pl. LV., fig. 13) has the biting process divided into five teeth, palp two-jointed, the first bulbously swollen on the inner margin, which bears four setæ, its outer margin furnished with a small bisetose laminar appendage; the last joint has three setæ on its inner margin and four at the apex. First maxilla (Pl. LXVII., fig. 3) composed of a short and broad setiferous lobe with a very large four-jointed palp; the maxillary lobe bears several plumose setæ and a papilla, from which spring two large and one small unguiform setæ; basal portion of the palp very stout, its first joint much broader than long, and bearing on its inner margin a fascicle of seven or eight plumose setæ; second joint about twice as broad as long, giving attachment on its distal margin, internally to two plumose setæ, and externally to a large one-jointed laminar appendage, which reaches as far as the extremity of the limb, has three setæ near the middle of its outer edge, and at its obliquely truncated apex nine very long and slender ciliated setæ; the third joint of the palp is much less stout than the preceding, and has a single stout plumose seta on its inner edge; terminal joint short, obliquely truncated at the apex, and bearing seven plumose setæ, the innermost of which is much longer than the rest. Second maxilla (Pl. LV., figs. 14, 15) three-jointed, two lower joints broad, the first being ciliated on its lower margin, which also bears one small distal seta; to its front margin is attached a semi-elliptic branchial plate, edged with setæ; second joint also having the lower margin finely ciliated, on each margin towards the extremity a densely ciliated seta, and at the extremity five densely ciliated but not long setæ; last joint very narrow and small, nearly thrice as long as broad, but only sufficiently wide to support the one short densely ciliated and somewhat unguiform seta, in which the limb ends. Caudal laminae (Pl. LV., fig. 16) deeply incised for the reception of each of the eight somewhat spiniform ungues, which are ciliated on their inner margins and not conspicuously dilated at their base; the ungues progressively increase in length from the first to the last, and the intercurrent projections of the caudal laminae are broadly triangular in form, with sub-truncate apices, except the last, which is chisel-shaped, sharp at the apex, and twice notched on its anterior margin. Length of female .63 mm.; male unknown.

*Habitat.*—Besides the localities enumerated in the “Monograph of recent British Ostracoda,” we have records of the occurrence of *P. orbicularis* in the following places:—Loch Fyne; Cumbræ, 16 fathoms; Rothesay and Kilchattan Bays; Clew and Birtirbuy Bays; Lough Swilly; off Valentia, 112 fathoms; New Grimsby Harbour, Scilly Islands, and at several points off the coasts of Durham and North Yorkshire.

*Distribution.*—In many places on the Norwegian Coast (G. O. Sars).

The surface-sculpture of this species is variable, and tends to become obsolete altogether in old and thick specimens; the reticulated pattern being visible only in what seem to be comparatively young specimens. Professor G. O. Sars notes that the motions of the animal are very lively and much resemble those of some of the Lynceidæ such as *Chydorus*; and this we are able to verify from our own observation. He also says that it is found chiefly in places where the bottom is covered with a thin layer of mud, and this accords fairly well with our own experience.

## 2. *Polycope punctata*, G. O. Sars.

(Pl. LXVII., figs. 9–12.)

1869. *Polycope punctata*, . . . Sars, G. O., "Nye Dybvandscrustaceer fra Lofoten" (Vidensk. Selsk. Forhand.), p. 27 (separate copy).

"Shell, seen from the side, almost circular, scarcely at all produced in front, the margins more evenly rounded than in *P. orbicularis*. Seen from above, rather tumid, the greatest width much exceeding half the length; valves thickly beset with minute depressed puncta, but only very slightly reticulated; colour very pale green."—(G. O. Sars.)

Basal joint of the antennule (fig. 10) about as long as the second joint; terminal joint more slender, and about two-thirds as long as the preceding; the whole limb devoid of hairs, except at the extremity, which bears five long, slender setæ. Mandible (fig. 11) divided at the apex into five sharp teeth, one of which is setiform; palp consisting of two very stout sub-quadrate joints, each of which is furnished with three setæ on its inner margin, the last also with four rather long apical setæ ("anterioribus 2 valde elongatis et curvatis," Sars); branchial lamina bearing only one short seta. Caudal laminæ (fig. 12) furnished with six unguis and with very small intercurrent marginal teeth; the unguis decrease only very slightly in length from behind forwards. Length .70 mm.

*Habitat.*—Coasts of Norway, in depths of 120–250 fathoms, not common (G. O. Sars). Some specimens dredged in Loch Fyne are doubtfully referable to this species.

This species is known to us only from a single authentic specimen kindly sent to us by Professor G. O. Sars. Of this specimen we give a figure (fig. 9). In shell structure it seems to differ scarcely at all from *P. orbicularis*, but the details of the antennules, mandibles, and caudal laminæ are sufficiently distinct to

separate it decisively from that species. So far as the shell is concerned, it seems, compared with *P. orbicularis*, to be more evenly rounded when seen laterally, to be devoid of reticulation and light yellowish-green in colour.

### 3. *Polycope pustulata*, G. O. Sars.

1890. *Polycope pustulata*, . . Sars, G. O., "Oversigt af Norges Crustaceer, II. Branchiopoda, Ostracoda, Cirripedia" (Christiania Vidensk.-Selsk. Forhand.), p. 53 (separate copy).

Shell, seen from the side, sub-circular; anterior extremity scarcely produced; posterior subtruncate, its superior angle distinct, inferior obsolete; dorsal margin strongly arcuate, and almost angulated in the middle; ventral evenly convex. Seen from above, the outline is narrowed in front, very wide behind, and showing on each valve behind the middle a rounded pustuliform eminence. Valves smooth, scarcely reticulated, minutely denticulated on the ventral margin. Colour as in *P. orbicularis*. Length .55 mm.

*Habitat*.—West coast of Norway, extremely rare.

This species we have never seen. Professor G. O. Sars, whose description is quoted above, has taken only one specimen, and it does not seem to have been noticed by any other naturalist.

### 4. *Polycope dentata*, G. S. Brady.

1866. *Polycope(?) dentata*, . . Brady, G. S., "Monograph of the Recent British Ostracoda," p. 472, pl. xxxv., figs. 58, 59.  
1894. ,, ,, . . Müller, G. W., "Die Ostracoden des Golfes von Neapel." p. 233, pl. vii., figs. 16–23; pl. viii., fig. 25.

We have not ourselves met with any specimens of this species other than that on which the original description was based, but G. W. Müller has recently found it sparingly in the Mediterranean, and has figured both sexes in his work on the Ostracoda of that region.

### Genus *POLYCOPSIS*, G. W. Müller.

Shell, as in *Polycope*, but serrated on the anterior margin. Antennules five-jointed, first and second joints large, the last three joints small, anterior margin of the second joint forming two massive digitiform prolongations, each of which

ends in a stout seta. Larger branch of antenna eight-jointed. Mandible bent sharply downwards, very small and slender, very feebly toothed, all except the external tooth nearly obsolete; palp large, the first joint bearing a small trisetose branchial lamina. Caudal laminae bearing eight marginal ungues, the first two much smaller than the rest, which gradually increase in length backwards; between the ungues the margin is only slightly produced in an angular fashion; no setose tufts on the abdomen proper. In other respects the animal resembles *Polycope*.

1. *Polycopsis compressa* (Brady & Robertson).

(Pl. LIV., figs. 11, 12; Pl. LXVII., figs. 4–8.)

1869. *Polycope compressa*, . . BRADY & ROBERTSON, "Ann. and Mag. Nat. Hist.," ser. IV., vol. iii., p. 20, pl. xxi., figs. 5–11.  
 1894.     ,,             ,,             . . MÜLLER, G. W., "Die Ostracoden des Golfes von Neapel." p. 238, pl. vii., figs. 34–36, 38; pl. viii., fig. 21.

Shell (Pl. LIV., figs. 11, 12), seen from the side, almost circular; dorsal and ventral margins very nearly equally arched; anterior margin dentated in a saw-like manner with about eighteen teeth, which gradually fade out at each end of the series (Pl. LXVII., fig. 7). Seen from above, the outline is compressed, ovate, greatest width situated in the middle and equal to somewhat less than half the length; anterior extremity moderately tapered, obtusely pointed; posterior broader and emarginate in the middle. Surface of the shell smooth, or finely punctate, and divided by a reticulated pattern into polygonal areas (Pl. LXVII., fig. 8).

Antennules (Pl. LXVII., fig. 4), especially the first two joints, very stout; the first joint bears only one marginal seta, second joint quite twice as long as the first, its outer margin produced into two long whip-like processes, which are very wide at the base (occupying nearly the whole length of the joint) and taper quickly to the points, each ending in a long lash; third joint very short and without setae; fourth more than twice as long as the third, and having a seta on each margin near the apex; last joint very minute, and carrying five extremely long and slender terminal setae.

Mandible (fig. 5) very small and bent on itself almost at a right angle (as in *Polycope*), its extremity divided into one sharp, well defined tooth, and a few much smaller and weaker processes; palp like that of *Polycope*, except that the laminar process of the first joint is trisetose. Ungues of the caudal laminae

(fig. 6) tapered evenly without any bulbous dilatation at the base, fringed on their concave margins with exceedingly delicate cilia; margins of the laminae produced between the unguis into small, sharp, triangular prominences; two similar, but sharper and more slender prominences are situated on the extremity beyond the last unguis. Length of the shell, .6 mm.

*Habitat*.—On an oyster-bed in Clifden Bay, Ireland, 4–6 fathoms; dredged off the Eddystone lighthouse, and amongst the Scilly Islands, 10–40 fathoms (B. & R.); off St. Monan's, Firth of Forth (Mr. T. Scott); Messina, inside the harbour, 8 fathoms (Dr. Dohrn); off Capri, Naples, 4 fathoms (A. M. N.).

The very remarkable development of digitiform processes on the antennules is the character which most decidedly separates this genus from its near ally, *Polycopse*, but the peculiar marginal denticulation of the shell, the trisetose mandible-palp, and the very slight development of the post-abdominal inter-ungual processes, are likewise of importance. We are indebted to the kindness of our friend Mr. Thomas Scott for the opportunity of examining and figuring freshly-taken specimens of this interesting species. We have thus been enabled to amplify and amend the original description which was drawn up from a scanty supply of dried specimens only.

## PLATYCOPA.

### Fam. CYTHERELLIDÆ.

Shell oblong, oblongo-ovate, or ovate, highly calcareous, and very hard. Seen from above, usually cuneate, or subcuneate; greatest breadth posterior. No rostrate process, or infero-anteal sinus. Valves unequal, the right the larger. Antennules seven-jointed, first two joints longer than the following, geniculated at their junction, following joints with numerous setæ, but no specialized sensory organ. Antennæ (Pl. LXVI., fig. 11) in form not unlike "the feet of *Copepoda*," flattened, consisting of two wide, sparingly setose basal joints, and two rami, one two-, the other three-jointed, joints flattened and densely setiferous. "Mandibulæ minimæ sed distinctæ, palpo magno pectinatim setoso instructæ. Membrorum sequentium tria modo adsunt paria minime pediformia, anteriora duo branchialia, posterius rudimentare" (G. O. Sars), but in the male the second and third maxillæ are much more largely developed, and suited for prehension. Copulative organs of the male elongated, cylindrical as in the *Conchæciadæ*. Posterior portion of the body consisting of many segments (at least ten in the female), and furnished dorsally with long setæ. Caudal laminae small, fringed with setæ, which are small in front, but gradually increase in length backwards. Ova lodged within the shell of the female

## Genus CYTHERELLA, Bosquet.

Shell usually elongated and compressed, very thick and hard; valves very unequal, the right much the larger and overlapping the left through the whole circumference; surface very variable in sculpture, usually smooth or punctate, but sometimes rugose. Muscle spots (Pl. LXVI., fig. 9) numerous, forming an oval patch near the centre of the valves, spots elongated or linear, and arranged in two rows, the axes of the spots convergent, so as to form a pinnate pattern. Antennules very large and stout, geniculated at the junction of the first and second joints; first two joints massive, and bearing marginal tufts of setæ, the remaining joints gradually decreasing in breadth, and setose on the margins. Antennæ composed of a stout, bi-articulate basal portion and two branches; outer branch composed of two joints; inner longer and three-jointed; both branches furnished profusely with long, stout setæ.

“Mandibles very weak and strongly bent towards the apex; biting edge obliquely truncated, and furnished with a pectinate series of slender teeth” (G. O. Sars); palp two-jointed, large, cylindrical, and only slightly curved, beset along the greater part of its length with a series of extremely long, slender, closely-packed, and backward-curved setæ (40–50 in number), and bearing near the base a small branchial appendage. First pair of maxillæ composed of three setiferous biting lobes and a very large two-jointed palp, which is armed, like that of the mandible, with numerous long setæ; inner margin of the basal portion divided into three arcuate lobes, each of which bears four rather rigid and short backward-pointing setæ; the last joint of the palp ends in two setæ and a club-shaped sensory appendage; there is also a very large branchial lamina with numerous, very long, marginal setæ. Second pair of maxillæ very small, composed of an ovate lamina, which bears a few marginal tooth-like setæ, and a narrow ovate branchial plate, furnished with about twenty-two setæ, the last two setæ of different structure from the rest and non-plumose; in the male the limb is much more largely developed, and forms a powerful prehensile organ, the basal point of which is hatchet-shaped. Third pair of maxillæ, in the female, “rudimentary, and forming a simple setiferous lobe” (Sars), bearing an almost semicircular branchial plate with about fourteen setæ; in the male, prehensile, and not unlike the preceding pair. Caudal rami small, narrow, fringed with setæ, which gradually increase in length from the first on the ventral margin to the last, which is situated behind the middle of the dorsal margin, is stouter than the rest, strongly curved and directed forwards over the dorsum. Copulatory organs of the male very large, curved, subcylindrical. Abdomen divided into numerous segments, which are bordered more or less completely by narrow chitinous bands.

Professor G. O. Sars long ago described, though he did not figure, the remarkable resemblances which exist between some of the limbs of *Cytherella* and those of certain other *Entomostraca* belonging to the widely separated orders of *Branchiopoda* and *Copepoda*. The resemblance, for instance, is at once apparent between the extraordinary doubly branched antenna of *Cytherella* and the thoracic swimming-feet of many of the *Copepoda*. The appendages of the mandibles and first pair of maxillæ, on the other hand, with their profuse armature of immensely long, pectinately arranged setæ, are wonderfully like the feet of the *Sididæ*. Another interesting point which seems hitherto to have escaped notice is the division of the posterior part of the body into numerous distinct segments, so that the abdomen of the animal recalls in its general aspect the tail of a lobster, or perhaps of some *Branchiopoda* such as *Chirocephalus*. Except by G. O. Sars, no example of *Cytherella* have yet been observed in the living condition;\* and in the European area, at any rate, it has never been taken except in considerable depths, nor in the tow-net either in the depths of the sea or at the surface. It may be assumed, therefore, though the profuse setose armature of the antenna would seem to adopt it for swimming, that it does not usually leave the bed of the sea to any great distance. Several recent species (about sixteen) have been described from various parts of the world, but except in the case of *C. abyssorum* and *C. serrulata*, the shell only has been seen. Numerous fossil species have also been recorded, but it is doubtful whether in some cases these species may not really belong to other genera.

1. *Cytherella serrulata*, n. sp.

(Pl. LXVI., figs. 3–6, 9–16; Pl. LXVII., figs. 15, 16.)

Shell of the female, seen from the side, subovate, almost reniform, a little higher in front than behind, greatest height equal to more than half the length; anterior extremity broadly and evenly rounded, sometimes slightly serrulated, but usually entire; posterior narrower, sloping rather steeply above, but broadly rounded below, and (in the adult female) fringed with a series of numerous minute teeth; dorsal margin straight, or very slightly arcuate, sloping gently downwards towards the posterior extremity; ventral distinctly sinuated in the middle. Seen from above, compressed, ovate, widest behind the middle, width equal to rather more than one-third of the length, subtruncate behind, with rounded angles, and tapering with a gentle curve towards the front, which is subacuminate. Surface of the valves smooth and polished, except the posterior extremity, which is roughened with numerous minute spines. Shell of the male much more compressed, and without marginal teeth. Seen from above, it is of almost equal width throughout, and quite thrice as long as broad; subtruncated

\* This was written before the publication of G. W. Müller's monograph.

behind, and obtusely pointed in front. Length of male, 1.05 mm.; of the female, 1.08 mm.

Antennules (Pl. LXVI., fig. 10) seven-jointed, first two joints stout, and about equal in length, first joint bearing on its inner margin a single short spine-like seta, and four very slender, long setæ, towards the outer margin is attached an extremely long seta which reaches as far as the apex of the fifth joint; second joint having three very stout plumose setæ near the distal end of the inner margin, and a very small seta on the outer margin; third joint almost triangular, the inner margin being extremely short, a single long seta at the outer apex; the remaining joints are all furnished with non-plumose setæ on their inner edges, the fourth, fifth, and seventh joints have three, the sixth only two; the fourth and sixth joints bear also slender setæ on their outer margins. All the stronger setæ of this limb are contracted at the base (fig. 10 *a*) so as to move, apparently, as on a hinge at the point of insertion.

Basal portion of the antennæ (Pl. LXVI., fig. 11) very massive, first joint much longer than the second, quadrate, and having two rather long, simple setæ on its outer margin; second joint subtriangular, dilated distally so as to form a lobe at the inner side, to which are attached three long setæ; to the outer margin are attached four or five small spinules; first joint of the outer branch of the antennæ with four large setæ on the inner half of the distal extremity, from the outer half of which springs the second joint, which is much narrower than the preceding, is truncated at the apex, and bears seven terminal setæ, which increase in length progressively from the outer to the inner side; inner branch with the first joint as broad as long, widened distally, and furnished with about twelve distal setæ; second joint much narrower, rather longer than broad, with one seta on the innermost side of the distal extremity and two (?) on the outer side; last joint about equal in length to the preceding, but much narrower, with one seta on the inner margin and two long and very slender setæ at the apex.

Mandible (Pl. LXVI., fig. 12) small, obliquely truncated at the extremity, where it is divided into a few very small teeth, palp large, obscurely two-jointed, first joint very long, beset along its entire length with a closely packed series of very long curved setæ, and bearing at its distal end a small digitiform process which ends in a moderately long, straight seta; second joint about one-fourth as long as the first, somewhat plough-share shaped, and ending in a long seta; at the base of the limb is a very minute branchial plate with about six setæ. Biting portion of the first pair of maxillæ (Pl. LXVI., fig. 13) composed of three small setiferous lobes, palp indistinctly triarticulate: the large basal joint of the palp bears a series of long curved setæ similar to those of the mandible palp, and is divided into two arcuate marginal lobes, each of which bears four spine-like, but slender, setæ; second joint subquadrate, about half as long as the preceding, and on the inner margin four spine-like setæ similar to those of the first joint,

the distal outer angle produced and furnished with two setæ; last joint sub-conical, truncate at the apex, where it bears two simply curved setæ and a sensory filament with a club-shaped extremity; attached to the maxilla is also a very large, branchial lamina with numerous (Sars counts thirty-three) ciliated setæ. Second pair of maxillæ consisting, in the female (Pl. LXVI., fig. 15), of a small ovate membranaceous lobe, which bears on its inner margin six small spine-like setæ, and near the base a few irregularly disposed small hairs: to the base of the maxilla is also attached an ovate branchial plate fringed with twenty-two setæ, all of them very delicately plumose, except the last two, which are also denser and heavier in outline than the rest. In the male (Pl. LXVI., fig. 14), the maxilla and branchial plate resemble those of the female, but there is in addition a powerful prehensile three-jointed palp, the basal joint of which is very long and irregular in build, its inner margin presenting two angular bisetose prominences between which is a large and deep excavation; the opposite margin is strongly convex proximally, and irregularly sinuous on its distal half; second joint slender, not much over one-third as long as the preceding, somewhat angularly dilated at the base, and near the apex bearing two rather long setæ; third joint half as long as the second and rather more slender, terminating in a small, but stout unguis. Attached to the base of the limb on the outer side of the first joint is a small lamina which ends in two long setæ. Third pair of maxillæ (in the female not observed), in the male (Pl. LXVI., fig. 16), forming a strong prehensile four-jointed limb, first joint very slender and bearing two long setæ on a papilla in the middle of its outer margin, and a single seta on the inner margin near its junction with the second joint; second joint hatchet-shaped, about equal in length to the preceding, its inner side forming a large angular eminence, to the middle of which are attached two small setæ, and near the distal end two rather stout unguis, one much larger than the other; third and fourth joints much more slender and naked except for a minute seta near the extremity of the last, which ends in a small unguis. At the base of the limb is a semicircular branchial lamina which gives attachment to a series of about fourteen delicately plumose filaments, and has also near the origin of the filament a crescentic row of flask-shaped follicles (?), one opposite to the base of each filament. The abdomen in both sexes is divided into about ten segments, which have chitinous margins, and are produced downwards like the pleural plates of a lobster; the dorsal surface is setiferous. Attached to the side of the male abdomen (Pl. LXVII., fig. 16) on the segment in front of the copulatory organs is a pair of small foliaceous appendages which are fringed distally and on the outer margin with numerous very delicate setæ. The caudal laminæ form the last abdominal segment (telson). Each of the five preceding segments, in the female (Pl. LXVII., fig. 15), is furnished with a single dorsal seta, while the seventh, eighth, and ninth segments from the extremity have dorsal fascicles of three or four long setæ, as well as some minute spine-like setæ.

Caudal laminæ, in the female, truncate at the extremity, which bears five unguæ; the stoutest is at the dorsal corner, has pectinated edges and is strongly and falcately curved, the second is small, the remaining three slender and each longer than the preceding; the lower, or front, margin of the lamina bears four peculiar setæ, flattened at the base, above which they are filiform, blunt-ended and pectinated. The hinder portion of the body in the male has each of the five segments preceding the caudal laminæ furnished only with a single dorsal seta, but is otherwise like that of the female. Copulatory organs of the male (Pl. LXVII., fig. 16) long, curvate, and cylindrical, resembling in form the same organs in *Conchæciadæ*; divided at the extremity into three small digitiform lobules.

Côte du Soudan, lat.  $22^{\circ} 49' N.$ , long.  $19^{\circ} 41' W.$ , 466–1168 fathoms, 12th–15th July, 1883; east of Canaries, 487 fathoms, 27th June, 1883; lat.  $27^{\circ} 31' N.$ , long.  $16^{\circ} 27' W.$ , July 7th, 1883; in lat.  $25^{\circ}$ , 217–528 fathoms, 9th July, 1883; off west coast of Morocco, latitude of El Arith, 600 fathoms; off Cap Blanc, 418–675 fathoms, and in other dredgings of which the precise localities are not indicated ("Talisman" Dredgings, M. le Marquis de Folin).

The figures and description of this species are taken entirely from specimens which have been kept in a dried condition for eleven or twelve years, some of which, however, after maceration in solution of potassium hydrate proved to be in good condition for dissection. We believe, therefore, that the foregoing will be found to be fairly accurate, though some of the more minute structures have escaped observation.

Amongst the numerous specimens of the shell which we have examined there is very considerable difference of contour, dependent, it may be, upon age and sex. The forms which we have figured are those which belong to the adult male and female.

## 2. *Cytherella abyssorum*, G. O. Sars.

(Pl. LXVI., figs. 1, 2, 15; Pl. LXVII., figs. 13, 14.)

1865. *Cytherella abyssorum*, . . . Sars, G. O., "Oversigt af Norges marine Ostracoder," p. 127.  
 1865. ,, *Beyrichi*, . . . Brady, "On New or Imperfectly Known Ostracoda" (Trans. Zool. Soc., vol. v.), p. 362, pl. lvii., fig. 3a, b.  
 1866. ,, *Scotica*, . . . Brady, "Brit. Assoc. Report," 1866, p. 211.  
 1866. ,, ,, . . . Brady, "Monog. Recent Brit. Ostrac.," p. 473, pl. xxxiv., figs. 18–21.

Shell of the female, seen laterally, subelliptical, of equal height throughout, height equal to considerably more than half the length, extremities equal and broadly rounded; superior margin almost straight, inferior very slightly sinuated

in the middle. Seen from above, the outline is subcuneate, widest behind, the greatest width being equal to half the length; the lateral margins diverge gently and in as lightly sinuated line from the front backwards; the anterior extremity is wide, subtruncate, or very obtusely rounded, the posterior subtruncate, with well rounded angles, and about twice as wide as the anterior. The surface of the valves is covered with rather large circular impressed puncta, and there is generally a more or less distinct transverse central depression. In the fresh condition the shell is furnished at the extremities with a few rigid hairs, those of the anterior margin being extremely long, but not visible in dried specimens. Colour, tawny-white or yellowish. The shell of the male does not differ much except in being more compressed when seen dorsally. Length of female, .95 mm.; of male, .90 mm. (G. O. Sars).

The soft parts of the animal do not differ materially from those of *C. serrulata*, but the second and third maxillæ are here figured.

Generally distributed round the coasts of Norway in depths of 100–300 fathoms (G. O. Sars and A. M. N.); Nice (Marquis de Folin). Taken also during the cruise of the “Valorous” in 410 fathoms (Station 6).

### 3. *Cytherella lævis*, Brady.

(Pl. LXVI., figs. 7, 8.)

1866. *Cytherella lævis*, . . BRADY, “Brit. Assoc. Report,” 1866, p. 211.

1866. „ „ . . BRADY, “Monog. Recent Brit. Ostracoda,” p. 474,  
pl. xxxiv., figs. 15–17.

Shell of the female, seen from the side, subelliptical, scarcely higher in front than behind, greatest height in the middle, and equal to two-thirds of the length, extremities well rounded, the posterior rather the narrower of the two; dorsal margin rather boldly and evenly arched, ventral nearly straight. Seen from above, the outline is subovate, twice as long as broad, the greatest width situated a little behind the middle; the anterior extremity is rather obtuse, the lateral margins diverging with a gentle curve to the posterior extremity, which is wide and truncated. Surface of the valves quite smooth, bearing a few short scattered hairs, the left valve narrow and almost straight dorsally, while the left is very strongly arched. Colour whitish. Length of female 1.05 mm.; of male 0.9 mm. The shell of the male is smaller, and the valves are flatter, so that when seen dorsally the lateral margins are less distinctly curvate.

Dredged on the west coast of Scotland (Mr. Jeffreys); west coast of Morocco, off Cape Cantin, 418 fathoms; off the coast of the Soudan, 400–460 fathoms (“Talisman” dredgings), and in a dredging of the “Travailleur” (1880), of which the precise locality is not indicated (Marquis de Folin).

## APPENDIX.

In this Appendix we notice the *Ostracoda* which have recently been described, together with new genera and species which have been or are here characterized; we give also a record of additional habitats in the case of some of the rarer species where the geographical range has by such habitats been extended.

Genus *CYCLOCYPRIS*, Brady & Norman, 1889.

(Brady & Norman, Pt. I., p. 70.)

Shell more or less ovate, and excessively tumid; valves may be punctate and slightly hispid, but are always polished and glossy. Antennæ five-jointed in female, six-jointed in male, having unguis of great length, and the setæ of third joint, about five in number, excessively long and reaching very far beyond the unguis. Mandible palp with last joint not slender, nor more than twice as long as broad. Lobes of the first maxillæ short, not so long as the first joint of the palp. Second feet having at the termination one small curved seta, a second seta of moderate length and a third very long, equalling almost the whole limb, upon which it is reflexed. Caudal rami of moderate length, strongly built, ending in two strong unguis, which are much curved at the apex and have a minute seta in front of them; the seta of the dorsal margin is situated far back, only a little beyond the middle of the limb. Males common.

1. *Cyclocypris globosa* (G. O. Sars).

(Brady & Norman, Pt. I., p. 71; Pl. XI., figs. 10–18; Pl. XIV., figs. 1, 2.)

2. *Cyclocypris serena* (Koch).

1889. *Cypria serena*, . . . . BRADY & NORMAN, p. 70.

1890. *Cyclocypris serena*, . . SARS, G. O., "Oversigt af Norges Crustaceer:  
II. Branchiopoda, Ostracoda, Cirripedia,"  
p. 55.

3. *Cyclocypris lævis* (O. F. Müller).

1889. *Cypria lævis*, . . . . BRADY & NORMAN, p. 69.

1890. *Cyclocypris lævis*, . . . SARS, G. O., *loc. cit.*, p. 55.

1891. " " . . . VÁVRA, "Monographié der Ostracoden Böhmens,"  
p. 68.

Professor G. O. Sars was certainly quite right in removing the two preceding species into the genus *Cycloocypris*. Our figures, Pt. I., Pl. XI., figs. 15, 16, were not correct as regards the setæ of the limbs drawn, of which we now give correct descriptions in the characters of the genus.

Of what we called in Part I. *Cypria Joanna* (Baird), we know nothing, and therefore do not assign it to this genus; the doing so would very probably be only giving another synonym.

### Genus CYPRIA, Zenker, 1854.

Shell subovate or reniform, subcompressed; valves punctate or striated. Antennæ five-jointed in female, six-jointed in male, ungues very long, the setæ of the third joint, about five in number, excessively long, reaching very far beyond the ungues. Mandible-palp with the last joint very long and slender, 4-5 times as long as broad. Lobes of first maxillæ very short, not nearly so long as the first joint of the palp. Second foot ending in two small setæ of equal length, and a third very long, which is reflexed upon the limb. Caudal rami of moderate length, strongly built, ending in two moderately robust ungues, only slightly bent at the apex, terminal seta minute, dorsal seta situated far back, only a little beyond the middle of the ramus. Males common.

1. *Cypria exsculpta* (Fischer).
2. *Cypria ophthalmica* (Jurine).
3. *Cypria lacustris*, Lilljeborg MS.

Pl. LXVIII., figs. 3, 4.

1890. *Cypria lacustris*, . . Sars, G. O., *loc. cit.*, p. 54.

*Charact. Specif.*—*C. ophthalmicæ* valde affinis, sed distinguenda testâ adhuc magis compressâ et paulo humilione limbo antice et postice latiore et valde hyalino. Animal sat pellucidum colore pallide flavescente maculis testæ minus distinctis et sæpius omnino deficientibus. Longit. testæ feminæ .80 mm.

*Habitat* in lacubus majoribus in profunditate 6-30 orgyarum. Sweden (Lilljeborg); Norway (G. O. Sars).

Professor Lilljeborg has kindly sent one of us (A. M. N.) specimens of this form. We can add nothing to Sars' description quoted above. The form certainly comes exceedingly near to that of *C. ophthalmica*. Whether it is to be regarded as a species or a variety is an open question. Some variation must be allowed in species, and there is certainly considerable variation in many *Ostracoda*, for example, in such common forms as *Cypris fuscata*, *virens*, and *incongruens*.

## Genus SCOTTIA, Brady &amp; Norman.

**Scottia Browniana** (T. R. Jones).

The habitat on the shores of Loch Fadd, in the Isle of Bute, where this species was found by Mr. T. Scott, is so remarkable, that it is worthy of further notice. It was visited by A. M. N. in company with Mr. D. Robertson, who knew the spot. A spring rises on a bank close to the loch, into which the water finds its way among the grass; the water is nowhere trickling more than two or three inches deep among the herbage. Here, amidst multitudes of *Difflugia*, *Scottia Browniana* lives, with *Ilyodromus Robertsoni*, *Herpetocypris reptans* and *tumefacta*, *Cypridopsis Newtoni*, *Candona candida*, and *Candonopsis Kingslei* as its companions.

## Genus CYPRIS.

Until quite lately males in this genus were unknown; and up to the present time no male has been found in the British islands.

In 1889 Professor G. O. Sars, in his Paper "On some Freshwater Ostracoda and Copepoda raised from dried Australian Mud" (Christ. Vidensk.-Selsk. Forhand.), described more fully the genus *Cyprinotus*, Brady, to which he assigned the British forms *Cypris salina*, Brady, and *Cypris fretensis*, Brady, and gave as one of the leading characters the fact that he had raised males of *Cyprinotus dentato-marginatus*, Baird, from the Australian mud. "Moreover," he wrote, "there is a feature that would seem to separate this genus," i.e. *Cyprinotus*, "very markedly from the genus *Cypris* (sens. strict.), and to bring it in closer relationship with the genus *Cyprois* of Zenker; as with the latter genus the propagation is sexual, and not as in the true genus *Cypris* exclusively parthenogetical, the males being almost as frequent as the females."

It is true that Dr. S. Fischer, as long ago as 1855 (*Beitrag zur Kenntniss der Ostracoden*), had recorded males in his *Cypris prasina*, *Cypris exserta*, *Cypris rivularis*, and *Cypris mareotica*, but the first would seem to be referable to Sars' genus *Cyprinotus*, the second is perhaps a *Candona*, the third also probably a *Candona*, the last doubtful, until now identified by Moniez as a true *Cypris*. More recently Professor C. L. Herrick ("Freshwater and Marine Crustacea of Alabama," Mem. Denison, Sci. Assoc., vol. i., 1887), states that he had found in Alabama males of a *Cypris* which he refers to *C. virens*, and of a species described by him as *C. modesta*. It remained, however, for M. R. Moniez finally to clear up all doubt on this matter. In two Papers published in 1891,\* he records the occurrence of

\* "Les Mâles chez les Ostracodes d'eau douce" (Revue Biol. du Nord. de la France), and "Faune des Lacs salés d'Algérie" (Mem. de la Soc. Zool. de France).

males in *Cypris virens*, Jurine; *C. incongruens*, Ramdohr; *C. mareotica*, Fischer; *C. unguolata*, Moniez; *C. balnearica*, Moniez; also in the genus *Herpetocypris*, as exemplified in *H. spinosa*, Moniez,\* an Asiatic species; and in the genus *Cypriopsis*, as evidenced in *C. villosa*, Jurine.

In the same year Vávra, in his work on the Ostracoda of Bohemia, described and figured the male of *C. incongruens*.

Among Hungarian Ostracoda recently sent to us for examination by Dr. Daday, we found *C. incongruens* to be the prevailing species, and in many of the gatherings both sexes were present.

Males of *Cypris* have thus been found in the south and east, but as far as we know the curious fact remains that no representatives of that sex have been observed in northern or western Europe north of Spain.

### *Cypris incongruens*, Ramdohr.

(Pl. LXIV., figs. 17, 18; Pl. LXVIII., figs. 22, 23.)

We figure the shell, second maxilla, and ejaculatory duct of the male of this species from a Hungarian specimen received from Dr. Daday.

### Genus CYPRINOTUS, G. S. Brady, 1886.†

This genus was established by shell characters to receive an Ostracod from Ceylon. Professor Sars has raised the same species, as well as the earlier described *Cypris dentato-marginata* of Baird, from Australian mud. Of this last species he has reared the males, and drawn up the following generic character:—

“Shell rather thin, compressed, oval or subtriangular, height considerably exceeding the half length; dorsal margin greatly vaulted; ventral margin almost straight. Valves rather unequal, the right being overlapped by the left both anteriorly and posteriorly, but sometimes dorsally produced far above the level of the latter. Free edges of the left valve smooth, and having at either extremity a rather broad hyaline border, those of the right armed with a regular series of small tuberculiform teeth. Inner duplicatures of both valves rather narrow. Natatory setæ of lower antennæ very elongate, reaching far beyond the terminal claws. Palpus of first pair of maxillæ rather narrow, last joint linear; masticatory lobes of middle length. Caudal rami narrow, claws smooth, seta of dorsal edge close to the claws. Propagation sexual. Prehensile palps of second pair of maxillæ in male rather powerful, unequal. Copulative organs compara-

\* Perhaps, however, this may prove not to be a true *Herpetocypris*.

† “Entomostraca collected by Mr. A. Haly in Ceylon.”—Linn. Soc. Journal—Zoology, vol. xix., p. 301.

tively small, with outer plate obtuse, linguiform. Ejaculatory tubes narrow, with numerous wreaths of spines, crown simple, not produced."

To the genus *Cyprinotus*, thus defined, is probably referable the following:—

***Cyprinotus prasinus* (S. Fischer).**

(= *Cypris salina*, Brady & Norman, Pt. I., p. 78).

Genus *STENOCYPRIS*, G. O. Sars, 1889.

"Shell very narrow and elongate, height by far not attaining half the length, ventral margin distinctly sinuated in front of the middle. Valves subequal, free edges smooth, inner duplicatures very large, especially at the anterior part. Natatory setæ of antennæ not reaching beyond the terminal claws. Palpus of first pair of maxillæ very narrow, cylindrical, last joint small, masticatory lobes long and narrow. Caudal rami rather large, more or less lamelliform, dorsal edges sometimes pectinate, claws very unequal, both coarsely denticulated, seta of dorsal edge absent, or very small, the apical one rather elongate. Propagation exclusively parthenogenetical."

Such is Sars' description of a genus described in his Paper "On some Fresh-water Ostracoda and Copepoda raised from dried Australian mud" (Christ. Vidensk-Selsk. Forhand. 1889). To this genus is referable the following European species:—

***Stenocypris fasciata* (O. F. Müller).**

*Herpetocypris fasciata*, . . . BRADY & NORMAN, 1st Part, p. 86, pl. ix., figs. 13, 14; pl. xii., fig. 1.

*Stenocypris* ,, . . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branchiopoda, Ostracoda, Cirripedia," Christ. Vidensk Selsk. Forhand., 1890, pp. 17 & 58. Separate copy.

Genus *HERPETOCYPRIS*, Brady & Norman.\*

***Herpetocypris glacialis*, G. O. Sars.**

(Pl. LXVIII., figs. 1, 2.)

1886. *Cypris Jurinii*, . . . . SARS, G. O., "Den Norske Nord. Exped. Crustacea," Pt. ii., p. 75 (nec Zaddach).

1890. *Herpetocypris glacialis*, . . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Christ. Vidensk-Selsk. Forhand.," 1890, p. 61.

\* In Part I., for *Erpetocypris* read *passim Herpetocypris*.

"Testa feminae sat ventricosa, a latere visa oblongo-ovata, vix duplo longior quam altior, altitudine maxima paulo ante medium sita, extremitate antica rotundata, postice obtusa, margine dorsali æqualiter arcuato, angulum tamen obscurum supra oculum formante, ventrali medio perparum sinuato; supra visa late fusiformis, latitudine maxima fere altitudinem æquante paulo pone medium sita, extremitate utraque acuminata. Valvulae subequales, sat tenues, nitidae, pilis dense obsitae. Color obscure fuscatus, supine macula magna viridi irregulari, utrinque in fascias duas angustas diagonales retro vergentes exserta. Setae natatoriae antennarum superiorum sat elongatae, eadem inferiorum vero brevissimae et rudimentares. Ungues apicales antennarum inferiorum et pedum primi paris subtiliter denticulati. Rami caudales mediocres apicem versus attenuati, unguibus dimidiam rami longitudinem superantibus, seta marginis dorsalis tenui unguibus approximata. Longit. testae, 1.60 mm."

*Distribution*.—Vardo, in East Finmark, and in marshes at Advent Bay, Spitzbergen (G. O. Sars).

Our figures are taken from types received from Professor G. O. Sars.

#### Genus ILYODROMUS, G. O. Sars.

"Contrib. Knowledge of Freshwater Entomostraca of New Zealand" (Vidensk. Skrifter, 1894), p. 38. Separate copy.

"Shell highly compressed and, seen laterally, oblong in form, with the dorsal edge straight in the middle, the ventral more or less sinuated. Valves generally not very unequal, the left one being in every case the larger, inner duplication very broad and shelf-like. Surface of shell in most of the species striated longitudinally. Setae of the superior antennae shorter than in *Candonocypris*, those of the inferior ones poorly developed, not reaching beyond the terminal claws. First pair of maxillae of nearly the same structure as in the genus *Candonocypris*. Caudal rami, on the other hand, much coarser, and armed with three strong claws, increasing in length distally. Animal quite devoid of swimming power. Propagation exclusively parthenogetical."

In this genus the caudal rami have "three instead of only two claws, the dorsal seta being here replaced with a claw of the same appearance as the other two."

To this description of Sars we may add that the chief teeth of the external member of the first maxillae are strongly dentated on the edges, as in the genera *Cypris* and *Herpetocypris*.

One of the following species Sars has himself referred to this genus; but to admit all the description of the dorsal margin of the shell will require modification.

1. *Ilyodromus olivaceus*, Brady & Norman.

1889. *Herpetocypris olivacea*, . . . BRADY & NORMAN, "Mon. Ostracoda-Podocopa,"  
Pt. I., p. 89, pl. i., figs. 3, 4.
1891. *Cypris* . . . VÁVRA, "Mon. der Ostracoden Böhmens.,"  
p. 88, fig. 29.
1894. *Herpetocypris* . . . CRONEBERG, "Beitrag sur Ostracoden Fauna  
der Umgegend von Moskau" (Bull de  
Moscou), p. 14, pl. vii., fig. 13 a-d.  
Separate copy.
1895. *Ilyodromus olivaceus*, . . . SARS, G. O., "Contrib. Freshwater Entom. of  
New Zealand" (Vidensk-Selks. Skrifter,  
1894), p. 39. Separate copy.

*Distribution*.—Bohemia (Vávra); near Moscow (Croneberg).

2. *Ilyodromus Robertsoni*, Brady & Norman.

1889. *Herpetocypris Robertsoni*, . . . BRADY & NORMAN, "Mon. Marine and Fresh-  
water Ostracoda-Podocopa," pt. I., p. 88,  
and woodcut.

*Distribution*.—Norway (G. O. Sars).

## Genus PRIONOCYPRIS,\* n. g.

Shell subtriangularly oblong, higher in front than behind, compressed; surface punctate and hirsute; the extremities more or less denticulately serrated. Antennæ with short setæ; animal incapable of swimming freely. Maxillæ having the claws of the outer member quite simple; palp with last joint slightly widening at the extremity, its length slightly exceeding the breadth. Caudal rami slender, the dorsal margin quite smooth; dorsal seta very near the terminal claws.

The shell in this genus is markedly distinct from that of *Herpetocypris reptans* and its allies. The caudal rami are smooth-edged, and not denticulated; but a very marked character consists in the simple claws of the outer member of the first maxillæ. These in *Cypris* and in *H. reptans* have their edges denticulated (see figures of these claws represented in many species figured by Vávra).

\* *πρίων*, a saw. Named from the serrated extremities of the valves.

**Prionocypris serrata** (Norman).

1889. *Herpetocypris serrata*, . . . BRADY & NORMAN, "Mon. Podocopa," p. 87.

Genus **CYPRIDOPSIS**, G. S. Brady, 1867.

Cypridopsis, as described by Brady ("Intellectual Observer," 1867, p. 117), was founded on the character of the caudal rami being "quite rudimentary, consisting of two slender, setiform processes, springing from a common base." Three species were included in it, *C. vidua*, *aculeata*, and *villosa*. The generic characters do not apply to the first, which must be removed from the genus.

The species described which should be retained in the genus are :—

1. **Cypridopsis aculeata** (O. G. Costa).

G. O. Sars thinks that the *Cypris aculeata* of Lilljeborg is the same species as that which was described many years before by O. G. Costa under the same name (*Fauna del Regno di Napoli Crostacei Cypris*, p. 11, Pl. III., fig. 5). It may be so, for Costa's description and figure agree closely with the northern form.

2. **Cypridopsis villosa** (Jurine).

3. **Cypridopsis Newtoni**, Brady & Robertson.

4. **Cypridopsis variegata**, Brady & Norman.

Genus **PIONOCYPRIS**,\* nov. nom.

= **Cypridopsis**, G. O. Sars, 1889 (*nec* Brady).

Sars' characters of the genus are as follows :—

Shell very tumid, more or less globular in form; dorsal margin boldly arched, ventral nearly straight. Valves subequal, rather thin, hairy, inner duplicatures narrow. Eye usually broad, transverse. Upper antennæ (= antennules) comparatively short, but having very long natatory setæ; lower antennæ rather powerful, with greatly elongated apical claws, and the natatory setæ reaching beyond their tips. Labrum very large and vaulted. First pair of maxillæ with palps and masticatory lobes narrow and elongate; second pair without any branchial lamella. Legs about as in *Cypris*. Caudal rami extremely small and narrow, but of quite normal structure, claws slender and setiform, three on each ramus, besides a very small apical bristle. Propagation exclusively parthenogenetical.

\* πῖων, fat, plump.

1. *Pionocypris vidua* (Müller), Pl. LXIV., fig. 19.= *Cypridopsis vidua*, Brady & Norman.

The caudal rami in this species differ from the figure given by Sars of the same organs in the Australian *Cypridopsis globulus*, G. O. Sars, and the definition of the genus requires slight modification to embrace them. Seen in situ from below, they exactly resemble the same organs in *Cypridopsis* (as limited above), that is, all that can be seen are apparently narrowly triangular rami ending in a single, very long seta. But when a lateral view is obtained (and in consequence of their extremely small size and their position it is not very easy to dissect the rami out and obtain this view), the ramus is seen to be unusually deep in proportion to its length, and to end in two very long subequal setæ, slightly behind which the dorsal margin bears a minute seta. We have not been able to detect any third minute apical seta, but it is possible that there may be one.

2. *Pionocypris obesa* (Brady & Robertson).

1869. *Cypridopsis obesa*, . . . BRADY & ROBERTSON, "Notes on a Week's Dredging in the West of Ireland," Ann. & Mag. Nat. Hist., ser. 4, vol. iii., p. 12, pl. xviii., figs. 5-7. Separate copy.
1870.     ,,         ,,         . . . *idem ibidem*, ser. 4, vol. vi., p. 15.\*
1874.     ,,         ,,         . . . BRADY, CROSSKEY, & ROBERTSON, "Post-Tert. Entom.," p. 128, pl. i., figs. 1-4.
1889.     ,,         *vidua*,     . . . (Variety). BRADY & NORMAN, "Mon. Ostrac. Pt. I., Podocopa," p. 89.
1890.     ,,         *obesa*,     . . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branchiopoda, Ostracoda, Cirripedia" (Christ. Vidensk-Selsk. Forhand.), p. 92.

Sars has restored this form to specific rank. We have expressed our conviction that it is only a variety of *P. vidua*, and have nothing to add to what may be said on either side of the question, but give a list of the localities in which the form *obesa* has been found.

*Habitat*.—Mullingar Canal, Dublin; Whittlesea Mere; Rivers Nene and Cam;

\* In this Paper Brady and Robertson give reasons which seemed to them to make it doubtful whether this form should be regarded as distinct, or as a variety of *C. vidua*.

Norfolk Broads (Brady & Robertson). River Ouse, near Lynn, Norfolk; Fulwell Cemetery, near Sunderland (G. S. Brady).

*Distribution*.—Rivers Maas and Scheldt in Holland (G. S. Brady). Norway (G. O. Sars).

*Fossil*.—Fluviatile clays, Hornsea, Yorkshire, and Branston Fen.

### 3. *Pionocypris picta* (Straus).

Genus *CYPROIS*, Zenker.

*Cyprois marginata* (Straus).

1821. *Cypris marginata*, . . . STRAUS, H. E., "Mémoire sur les Cypris Mém. du Mus.," vol. vii., p. 59, pl. i., figs. 20–22.  
 1889. *Cyprois flava*, . . . . BRADY & NORMAN,<sup>E</sup> "Monograph Ostracoda," I., p. 97, pl. viii., figs. 18, 19; pl. xii., figs. 13–21, 38.  
 1890. „ *marginata*, . . . SARS, G. O., "Oversigt af Norges Crustaceer," II., p. 54.

We think that Professor Sars has rightly referred this to the hitherto unidentified *C. marginata* of Straus.

Genus *ILYOCYPRIS*, Brady & Norman.

Professor G. O. Sars is perhaps right in regarding two species as having been confounded by authors under the name *Cypris gibba*, Ramdohr. The differences in the two forms had long been a matter of perplexity to us.

### 1. *Ilyocypris gibba* (Ramdohr).

(Pl. LXVIII., figs. 20, 21.)

1868. *Cypris gibba*, . . . BRADY, "Mon. Brit. Ostrac.," *partim*, pl. xxiv., fig. 54; pl. xxxvi., fig. 2.  
 1889. *Ilyocypris gibba*, . . . BRADY & NORMAN, "Monog. Marine & Freshwater Ostracoda," p. 107 *partim*, pl. xxii., figs. 1–5.  
 1890. „ „ . . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," p. 58.  
 1891. „ „ . . . VÁVRA, "Monog. der Ostracoden Böhmens," p. 57, fig. 17.  
 1894. „ „ . . . Var. *tuberculata*. KERTESZ, K., "Daten zur Ostracoden-Fauna der Umgegend Szeghalom's. Természetrájsi Füzetek," 1893 (1894), p. 169, pl. vi., figs. 1–12.

In this form the shell is not only transversely bisulcated, but also tuberculated (see Brady, 1868, fig. 24. Kertész, figs. 1, 2 represent a more than commonly tuberculated form), and the antennæ have the antepenultimate joint furnished with a long brush of setæ which extend beyond the terminal claws (see Brady, 1868, Pl. xxxvi., figs. 2, 6, and Brady & Norman, Pl. xxii., fig. 1).

It is the form figured by T. R. Jones in "Tertiary Entom.," 1856, Pl. i., fig. 3 a, as *Cypris gibba*; by Fischer, "Das Genus Cypris," Pl. v., figs. 5-8, as *Cypris biplicata*; and by Brady, Crosskey, and Robertson, "Mon. Post-Tertiary Entomostraca," as *C. gibba*, Pl. xv., figs. 5, 6.

## 2. *Ilyocypris Bradii*, G. O. Sars.

(Pl. LXIII., figs. 22, 23; Pl. LXVIII., figs. 18, 19.)

1868. *Cypris gibba*, . . . BRADY, "Mon. Brit. Ostrac." *partim*, pl. xxvi., figs. 47-50.  
 1890. *Ilyocypris Bradii*, . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," p. 50.  
 1891. ,, *gibba*, . . Var. *repens*. VÁVRA, "Monog. der Ostracoden Böhmens," p. 60, fig. 18.

*Ilyocypris Bradii* is distinguished from *I. gibba* by the characters—1st, that the shell, though similarly bisulcated transversely, is not tuberculated; and 2nd, that the setæ of the antepenultimate joint of the antennæ are very short, and scarcely reach the bases of the terminal spines (Pl. LXIII., fig. 22).

The following synonyms appear to be referable to this form rather than to the last:—*Monoculus puber*, Jurine (?), and *M. bistrigatus*, Jurine (junior?); *Cypris biplicata*, Koch; *C. bistrigata*, Zaddach; *C. sinuata*, Fischer; and *C. bistrigata*, Lilljeborg. It appears to us to be unquestionably *C. biplicata*, Koch; and that name it will probably have to bear, if not one of Jurine's names.

## Genus CANDONA.

Professor G. O. Sars has described several forms very closely allied to *C. pubescens*, which he considers distinct. To his usual great kindness we are indebted for specimens of these Candonæ, and we here quote his descriptions, and add illustrations from his specimens.

### *Candona compressa*, Koch.

= *Candona pubescens*, Brady & Norman.

Sars would retain Koch's two species, and attribute the name *C. compressa* to

the British form hitherto described by us. Of *C. pubescens*, Koch (G. O. Sars), he gives the following characters:—

***Candona pubescens*, Koch.**

(Pl. LXIII., fig. 24; Pl. LXIV., figs. 20, 21; Pl. LXVIII., figs. 7–9.)

1837. *Cypris pubescens*, . . KOCH, C. L., "Deutschlands Crustaceen Myriapoden und Arachniden," H. XI., No. 6.

1890. *Candona* ,, . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," Vidensk-Selsk. Forhand., p. 64.

"Testa feminae a latere visa ovato-subreniformis, altitudine maxima dimidia longitudine multo majore in parte postica sita, extremitate antice anguste rotundata, postica sat expansa adque angulum inferiorem obtusa; margine dorsali postice valde arcuato antice declivi, ventrali leviter sinuato; supra visa oblonga, latitudine maxima altitudine multo minore in medio sita, extremitate antica angustiore. Testa maris eadem feminae paulo major et postice magis expansa, margine ventrali distinctius sinuato. Valvulae parum inaequales, pilis longissimis ubique hispidae, albae, opacae, parum nitidae, tuberculis nullis visibilibus. Rami caudales breves, vix flexuosi, apicem versus sensim attenuati, unguibus subaequalibus dimidio ramo multo longioribus, margine altero subtiliter denticulato, seta marginis dorsalis haud elongata ad partem ultimam tertiam rami sita. Longitudo testae maris 1.30 mm."

*Habitat*.—Pond in Wanstead Park, Essex, and at Pavenham, Bedfordshire (Mr. Scourfield).

*Distribution*.—In marshes in the neighbourhood of Christiania (G. O. Sars).

For specimens from the English localities we are indebted to the kindness of Mr. Scourfield. Figures from these specimens are given in Plate LXVIII. The second maxilla and caudal ramus are shown in Plates LXIV. and LXIII.

***Candona stagnalis*, G. O. Sars.**

(Pl. LXVIII., figs. 14–17.)

1890. *Candona stagnalis*, . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," Christ. Vidensk-Selsk. Forhand., p. 69.

1891. ,, *ambigua*, . . SCOTT, T., "Invertebrate Fauna of Inland Waters of Scotland," Ninth Report Fishery Board for Scotland, p. 277, pl. iv., figs. 7 a–c, ♂.

Having received through the kindness of the describers type specimens of the

above two named *Candonæ*, we find them to be, unquestionably, the same species, which is nearly allied to *C. Zenkeri*. We give Sars' description in his own words, so as to do full justice to his views with respect to the several very closely allied forms which he regards as distinct:—

“Testa feminæ a latere visa oblongo-subreniformis, fere duplo longior quam altior, extremitate antica rotundata, postica quam in *C. compressa* minus expansa, supine vix angulata, inferne obtusa, margine dorsali subrecto et parum modo declivi, ventrali leviter sinuato; supra visa oblongo-ovata, latitudine maxima altitudine paulo minore pone medium sita, antice quam postice magis attenuata. Testa maris ab eadem feminæ parum discrepans, extremitate postica paulo magis expansa et ad angulum inferiorum mutica. Valvulæ parum inæquales, læves, nitidæ, subpellucidæ, sparse pilosæ. Rami caudales fere recti et sensim attenuati, unguibus sat fortibus et margine altero conspicue dentatis, seta marginis dorsalis haud magna, ad partem ultimam tertiam rami affixa. Longitudo testæ, 0·90 mm.”

*Habitat*.—Lochgelly Loch, Fifeshire (Thomas Scott).

*Distribution*.—In ditches and marshes round Christiania (G. O. Sars).

#### ***Candona Zenkeri*, G. O. Sars.**

(Pl. LXIII., fig. 25; Pl. LXVIII., figs. 12, 13.)

1890. *Candona Zenkeri*, . . Sars, G. O., “Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.” Vidensk-Selsk. Forhand, p. 66.

“Testa feminæ sat compressa, a latere visa oblonga-reniformis, duplo circiter longior quam altior, extremitate antice obtuse rotundata, postica sat expansa adque angulum inferiorem arcuata et limbo tenui hyalino circumdata, margine dorsali medio recto et paulo declivi, angulo distincto et antice et postice terminato, ventrali profundius sinuato; supra visa anguste oblonga, latitudine maxima altitudine multo minore fere mediana, antice quam postice magis attenuata. Testa maris ut vulgo in parte postice expansa, angulo superiore sat prominente. Valvulæ sparse et breviter pilosæ, semipellucidæ, lævis, nitidæ, margaritaceæ, dextra sinistra nonnihil majore. Rami caudales subrecti, attenuati, unguibus dimidiam rami longitudinem vix superantibus, sublævibus, seta marginis dorsalis brevi ad partem ultimam quartam rami affixa. Longitudo testæ, 0·88 mm.”

*Habitat*.—It is a British species, having been found thirty years ago by A. M. N. in a pond at Ferry Hill, in the county of Durham, remaining since in his collection as a doubtful form.

*Distribution*.—Rare in marshes round Christiania (G. O. Sars).

**Candona Kingsleii**, Brady & Robertson.

Vávra (*loc. cit.* p. 54) has established a genus *Candonopsis* to receive this species. He has only seen the male, but from it draws the following generic characters:—

Antennæ six-jointed, with two peculiar sense organs between the fourth and fifth joints. Mandible palp very long. Second maxillæ with a trisetose branchial plate. Caudal rami slender; seta of the dorsal margin absent.

*Distribution*.—Bohemia (Vávra); Norway (Sars).

**Candona rostrata**, Brady & Norman.

*Distribution*.—Neighbourhood of Moscow (Croneberg); Norway (G. O. Sars).

Besides the species referred to in the preceding notes, Professor G. O. Sars has, in his "Oversigt," added the following to the species previously known as included in the fauna of Norway:—

*Cypria exsculpta* (Fischer).

*Cypridopsis aculeata*, Brady = *Potamo-*

*Cypria elliptica*, Baird.

*cypris aculeata*, Sars.

„ *reticulata*, Zaddach = *affinis*,

*Candona fabæformis* (Fischer).

„ *obliqua*, Brady. [Fischer.

„ *hyalina*, B. & R.

„ *crassa*, O. F. Müller.

„ *acuminata* (Fischer).

*Herpetocypris Jurinii* (Zaddach).

„ *tumefacta* (B. & R.).

Genus BYTHOCYPRIS, G. S. Brady.

Professor Sars removes *Bairdia obtusata*, G. O. Sars, and *B. complanata*, Brady, into this genus.

**Argilloëcia cylindrica**, G. O. Sars.

*Distribution*.—East Finmark, at Vadsö, in 10 fathoms, and Klosterelv Fiord, tidemarks (A. M. N.).

**Cythere confusa**, Brady & Norman.

*Distribution*.—Vadsö, East Finmark (A. M. N.).

**Cythere pellucida**, Baird.

*Distribution*.—East Finmark (A. M. N.).

**Cythere gibbosa**, Brady & Robertson.

*Distribution*.—Klosterelv Fiord, East Finmark, tidemarks (A. M. N.).

***Cythere limicola*, Norman.**

*Distribution*.—Fiords of East Finmark, in 5–30 fathoms (A. M. N.).

***Cythere cluthæ*, B. C. & R.**

*Distribution*.—Living in 125–150 fathoms, Varanger Fiord, and 20–30 fathoms, Bog Fiord, East Finmark (A. M. N.).

***Cythere villosa* (G. O. Sars).**

*Distribution*.—East Finmark (A. M. N.).

***Cythere*(?) *semiovata*, T. Scott.**

(Pl. LXIII., figs. 14, 15.)

1890. *Cythere*(?) *semiovata*, . . . SCOTT, T., "Addit. Fauna, Firth of Forth," Eighth Ann. Rep., Fishery Board for Scotland, p. 321, pl. xii., figs. 1, 2.

"Shell, seen from the side, semioval, dorsal and ventral margins nearly parallel; dorsal margin a flattened curve, sloping downwards posteriorly, and forming with the nearly straight ventral margin a somewhat bluntly angular extremity; anterior end sharply rounded below, then curving obliquely upwards and backwards till it merges in the dorsal margin. Seen from above, the width is greatest near the anterior end, but varies little for about three quarters of the length, when the sides converge and form posteriorly a somewhat wedge-shaped extremity. The anterior end is broadly rounded, inclining to angular in the middle, where the valves meet; greatest breadth equal to height; height about one-third the length. Surface of the valves smooth, but having a slightly resinous appearance. Length, .35 mm.

"*Habitat*.—Off St. Monica; not very rare. Specimens of this form have been dredged on several occasions at this place. Depth, 12–14 fathoms; bottom clear gravel and sand. The animal has not yet been made out; the species is therefore for the present doubtfully referred to *Cythere*."

We quote here the original description and give illustrations from one of Mr. Scott's specimens kindly lent to us for that purpose. We, however, think that the description is erroneous in taking the anterior for what is really the posterior extremity of the shell. It is a very minute form; but we do not recognise it as the young of any species known to us.

**Cythere tuberculata** (G. O. Sars).

*Distribution*.—Vadsö, shallow water; and tidemarks, Klosterelv Fiord, East Finmark (A. M. N.).

**Cythere concinna**, T. R. Jones.

*Distribution*.—Tidemarks and shallow water, Vadsö, Bog and Klosterelv Fiords, East Finmark (A. M. N.).

**Cythere emarginata** (G. O. Sars).

*Distribution*.—East Finmark, living between tidemarks and in shallow water, Vadsö and Klosterelv Fiords (A. M. N.).

**Cythere finmarchica** (G. O. Sars).

*Distribution*.—Vadsö and Lang Fiords, living between tidemarks and in shallow water (A. M. N.).

**Cythere angulata** (G. O. Sars).

*Distribution*.—East Finmark, living between tidemarks and in shallow water at Vadsö and in Klosterelv Fiord (A. M. N.).

**Cythere mirabilis**, G. S. Brady.

*Distribution*.—Living, Varanger Fiord, 125–150 fathoms, and Bog Fiord, 20–30 fathoms (A. M. N.).

**Cythere dunelmensis**, Norman.

*Distribution*.—East Finmark, tidemarks to 100 fathoms, Vadsö, Bog, and Klosterelv Fiords (A. M. N.).

**Limnocythere inopinata** (Baird).

(Pl. LXVIII, figs. 5, 6.)

1888. *Limnocythere incisa*, . . DAHL, "Die Cytheriden der westlichen Ostsee Zool. Jahrbüch." Bd. III., 1888, p. 20, pl. ii., figs. 49–58.

1890. ,, ,, . . SARS, G. O., "Oversigt af Norges Crustaceer: II. Branch. Ostrac. Cirrip.," Christ. Vidensk. Selsk. Forhand., p. 69.

We give a figure of *Limnocythere incisa* received from Professor G. O. Sars. We regard it simply as a variety of *L. inopinata*.

*Distribution*.—G. O. Sars records both *L. inopinata* and *L. incisa* from Norway.

***Limnocythere compressa*, Brady & Norman.**

1889. *Limnocythere inopinata*, . . . Var. *compressa*. BRADY & NORMAN, "Monog. Marine and Freshwater Ostracoda" (Trans. Roy. Dub. Soc., ser. 2, vol. iv.), p. 170, pl. xvii., figs. 18, 19.

We have come to the conclusion that this Ostracod must be regarded as distinct from *L. inopinata*, to which we had assigned it as a variety. We have now found it in a second locality. In both habitats the form is constant, and shows no approach to *L. inopinata*, from which it is at once distinguished by the much more gibbous central portion of the valves and more concave ventral margin, but especially by the extraordinary compression of the anterior and posterior extremities.

*Habitat*.—Whitefield Loch, Wigtonshire; Loch Aber, Kircudbrightshire (A. M. N.).

***Limnocythere Sancti-Patricii*, Brady & Robertson.**

*Distribution*.—Norway (G. O. Sars).

***Cytheridea*(?) *monensis*, n. sp.**

(Pl. LXVIII., figs. 10, 11.)

Shell, seen from the side, subovate, greatest height equal to rather more than half the length, and situated near the middle; anterior extremity evenly rounded, posterior also well rounded, but narrower; dorsal margin sloping with a gentle curve towards the front, and in a slightly sinuated line backwards, the posterior angle being quite rounded away; ventral margin nearly straight. Seen from above, the outline is subcuneate, though not very much wider behind than in front, and the left valve overlaps the right at both extremities; greatest width at the posterior extremity, and equal to less than half the length; anterior extremity wide and rounded, with abruptly converging sides, mucronate in the middle; posterior subtruncate, the margin of each valve almost rectilinear, and meeting its neighbour at an obtuse angle. Surface of the shell covered with large, deeply impressed subrotund pittings; anterior border fringed below the middle with a series of short, bluntly rounded teeth, which form a sort of crenulated crescentic flange, the posterior ventral angle produced in a somewhat similar fashion, but with a smaller number of teeth, which are also more irregular, and give a marked prominence to the angle of the shell. Length, 0.65 mm.

One specimen only of this species was taken in a tide-pool at Port St. Mary, Isle of Man (G. S. B.). In general aspect, and more especially in its style of surface-sculpture, it is not unlike *Cythere marginata*, but it lacks the tubercular elevation over the anterior hinge-joint; the posterior ventral angle is prominent, while in *C. marginata* that part is much cut away, and the outline, as seen from above, is altogether different. On the hinge-line there is an appearance of crenulation, which, together with the general outline of the shell, leads us to refer the species provisionally to the genus *Cytheridea*.

***Cytheridea papillosa*, T. R. Jones.**

*Distribution*.—East Finmark, common (A. M. N.).

***Cytheridea punctillata*, G. S. Brady.**

*Distribution*.—Vadsö; Lang, Bog, and Klosterelv Fiords, in 5–100 fathoms (A. M. N.).

***Cytheridea Sorbyana*, T. R. Jones.**

*Distribution*. — Fine living examples in Klosterelv Fiord, East Finmark, 5 fathoms (A. M. N.).

***Eucythere declivis* (Norman).**

*Distribution*.—In 0–25 fathoms, together with var. *Argus*, G. O. Sars; East Finmark (A. M. N.).

***Krithe bartonensis*, T. R. Jones.**

*Distribution*.—Vadsö, in 5–15 fathoms.

***Loxoconcha tamarindus*, T. R. Jones.**

*Distribution*.—Living between tidemarks and in shallow water, Vadsö and Klosterelv Fiord (A. M. N.).

***Loxoconcha fragilis*, G. O. Sars.**

*Distribution*.—A single living specimen between tidemarks in Klosterelv Fiord (A. M. N.).

***Xestoleberis depressa*, G. O. Sars.**

*Distribution*.—East Finmark, common (A. M. N.).

***Cytherura affinis*, G. O. Sars.**

*Distribution*.—Shallow water, Vadsö; and tidemarks, Klosterelv Fiord (A. M. N.).

***Cytherura sella*, G. O. Sars.**

*Distribution*.—Vadsö, 20–30 fathoms (A. M. N.).

***Cytherura undata*, G. O. Sars.**

*Distribution*.—0–25 fathoms, East Finmark, in several places (A. M. N.).

***Cytherura grœnlandica*, Brady & Norman.**

*Distribution*.—Vadsö, in 5–25 fathoms; new to Europe (A. M. N.).

***Cytherura similis*, G. O. Sars.**

*Distribution*.—Vadsö, with the last (A. M. N.).

***Cytherura mucronata*, T. Scott.**

(Pl. LXIII, figs. 18, 19.)

1890. *Cytherura mucronata*, . . SCOTT, T., “Additions to the Fauna of the Firth of Forth,” Eighth Ann. Rep. Fishery Board for Scotland, p. 323, pl. xii., figs. 3–5.

“Shell, seen from the side, elongate, narrow; height about equal at both ends, length two and a-half times the height; dorsal margin nearly straight, ventral margin slightly and evenly concave, posterior end much produced, and wedge-shaped, forming a ‘beak,’ which is situated below the middle; anterior margin broadly rounded, somewhat produced in the middle. Seen from above, oval, with the ends acuminate; the margin at each end, especially at the anterior, is produced so as to form a distinct ‘mucro.’ The surface is marked with indistinct raised lines, which are somewhat irregularly distributed; the breadth is equal to the height. Length, .33 mm.”

*Habitat*.—Off St. Monace; not very rare.

We figure one of Mr. Scott’s specimens, but believe that it must be referred to the young of *Cytherura producta*, Brady.

***Cytherura bodotria*, T. Scott.**

(Pl. xiv., figs. 16, 17.)

1890. *Cytherura bodotria*, . . SCOTT, T., “Additions to the Fauna of the Firth of Forth,” Eighth Ann. Rep. Fishery Board for Scotland, p. 322, pl. xii., figs. 6, 7.

“Shell, seen from the side, of nearly equal height throughout; dorsal and ventral margins nearly straight, the former is slightly convex towards the anterior extremity; anterior margin evenly rounded, posterior extremity with a short

beak situated about the middle, its termination narrow, truncate. Seen from above, ovate, slightly constricted in front, where the valves meet. At the posterior end the middle is bluntly mucronate, and the sides are produced to an acute angle, so as to impart to it a somewhat tridentate appearance; dorsal ridge prominent, where it bends downwards in front. Surface sculptured with flexuous longitudinal riblets, crossed by a few indistinct ones arranged irregularly. Length, .5 mm.; breadth, three-fifths the length; height, fully one-third the length.

“*Habitat*.—Off St. Monace, in 12 to 14 fathoms; bottom sand and gravel rare.

“This species somewhat resembles *Cytherura acuticostata*, but differs in being not so stout, and in having the valves produced backwards, so that the posterior extremity of the shell has a tridentate form.”

We figure Mr. Scott's type specimen, which he has kindly sent to us for that purpose. We believe that it must be regarded as the young of *Cytherura acuticostata*. We have not a series down to the very young of that species; but in the young of the genus *Cytherura* the beak occupies a much larger proportion of the shell, and is thus more prominently conspicuous than in the adult. We have especially noticed this to be the case in *C. cornuta* and *C. nigrescens*; and a very fine series of the young of the former species shows that the lateral projections are also more acute in the young than in the adults. We figure the young of the two last-mentioned species in illustration of our remarks (Pl. LXIII., figs. 20, 21.)

***Cytherura nigrescens* (Baird).**

*Distribution*.—East Finmark, tidemarks (A. M. N.).

***Cytherura rudis*, G. S. Brady.**

*Distribution*.—Entrance of Vadsö Harbour, in 15–25 fathoms; new to Europe. (A. M. N.).

***Cytherura cellulosa* (Norman).**

*Distribution*.—Vadsö, 20–30 fathoms.

***Cytheropteron latissimum* (Norman).**

*Distribution*.—East Finmark, in 0–25 fathoms (A. M. N.).

***Cytheropteron nodosum*, G. S. Brady.**

*Distribution*.—A single specimen, Vadsö, 15–25 fathoms (A. M. N.).

***Bythocythere constricta*, G. O. Sars.**

*Distribution*.—Vadsö, tidemarks (A. M. N.).

**Bythocythere recta**, G. S. Brady.

*Distribution*.—One small living specimen dredged in 20 fathoms to the east of Vadsö, Finmark (A. M. N.).

**Pseudocythere caudata**, G. O. Sars.

*Distribution*.—Vadsö, in 5–15 fathoms (A. M. N.).

**Paradoxostoma variabile** (Baird).

*Distribution*.—Tidemarks, Vadsö and Klosterelv Fiord (A. M. N.).

**Paradoxostoma rostratum**, G. O. Sars.

*Distribution*.—Three specimens among weeds between tidemarks, at Vadsö (A. M. N.).

**Paradoxostoma inflexum**, Brady & Norman.

(Pl. LXIII., figs. 12, 13.)

1891. *Paradoxostoma inflexum*, . . . BRADY & NORMAN, "In Norman Marine Crustacea Ostracoda of Norway," Ann. and Mag. Nat. Hist., ser. 6, vol. vii., p. 118, and woodcut.

Shell, seen from the side, siliquose, greatly curved, greatest height equal to two-fifths of the length, behind the middle; anterior half of much less height than the posterior, and bending downwards; anterior extremity narrow, but well and evenly rounded; dorsal margin strongly arched throughout, without any angularity in any part, posterior declination much more sudden than the anterior; ventral margin deeply concave in front of the middle, behind the middle gently convex, the hinder portion of the shell thus becoming much higher than the anterior. Seen from above, very narrow, greatest width not more than half the height, sides nearly flat, both extremities very narrow, but the anterior more acute than the posterior. Length, .4 mm.

Tidemarks, among weeds, Vadsö, East Finmark (A. M. N.).

There are only two Ostracoda which this very small species can be said to approach at all in shape, and of which it might be suggested that it was the young. These are *Paradoxostoma Normani* and *Sclerochilus contortus*. With the young of the same size in these species it has been compared, and it differs *in toto*. The young of the first of these species is very much shorter and higher, in fact shorter and higher than the adult, and less incurved. The young of *Sclerochilus*

*contortus* is very nearly of the same shape as the adult, the extremities much more nearly equal than in this species, and consequently the whole shape different; it is also more tumid. It is possible that the present species may hereafter prove to be a *Sclerochilus* and not a *Paradoxostoma*. The specimens described had been dried before they were noticed, though living when collected.

***Paradoxostoma* (?) *affine*, T. Scott.**

(Pl. LXIII., figs. 10, 11.)

1890. *Paradoxostoma*(?) *affine*, . . SCOTT, T., "Additions to the Fauna of the Firth of Forth," Eighth Ann. Rep. Fishery Board for Scotland, p. 325, Pl. xii., figs. 8, 9.

Shell, seen from the side, elongate, subovate, highest a little behind the middle; dorsal margin evenly but not boldly arched, inferior nearly straight, slightly sinuate towards the anterior extremity; anterior extremity rather higher than the posterior, and the margins of both evenly rounded; surface smooth, with a few irregular scratched lines. Outline, seen from above, compressed, ovate, the posterior half of nearly equal breadth, with the extremity obtusely pointed. Anteriorly the shell is more compressed, the extremity being somewhat acuminate; breadth about equal to height, and one-third the length. Length, .42 mm.

The form resembles a small *P. arcuatum*, but is not so narrow posteriorly, and the greatest breadth is nearer the posterior extremity. It seems to us, however, to resemble even more closely the genus *Aglaia*, and quite possibly may be the young of *A. complanata*. Our figures are taken from one of Mr. Scott's specimens.

*Habitat*.—Off St. Monace; not common (T. Scott); Inverary 25–40 fathoms (A. M. N.).

***Paradoxostoma flexuosum*, G. S. Brady.**

This appears to be a species of remarkable variability, and it seemed to us right after examination of a very large number of specimens from various localities to unite *P. tenerum*, B. C. & R., with it. Perhaps more than one species is confused under the name *P. flexuosum*.

**Genus *Cytherois*, W. Müller.**

G. O. Sars removes his *Paradoxostoma vitreum* into the genus *Cytherois*.

# WORKS AND PAPERS CONSULTED IN THE PREPARATION OF THIS MONOGRAPH.

(*Addenda to List in Vol. iv., pp. 258-264.*)

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EXPLANATION OF PLATE L.

## PLATE L.

### *Asterope mariæ.*

#### Figure

1. Animal (male), seen from right side ; right valve removed,  $\times 50$ .

<i>a.</i> ,	.	.	.	Antennule.
<i>b.</i> ,	.	.	.	Basal portion of antenna.
<i>c.</i> ,	.	.	.	Swimming branch of antenna.
<i>d.</i> ,	.	.	.	Secondary branch of same.
<i>e.</i> ,	.	.	.	Mandibular foot.
<i>f.</i> ,	.	.	.	First maxilla.
<i>g.</i> ,	.	.	.	Second maxilla.
<i>h.</i> ,	.	.	.	Third maxilla.
<i>i.</i> ,	.	.	.	Caudal lamina.
<i>k.</i> ,	.	.	.	Branchiæ.
<i>l.</i> ,	.	.	.	Vermiform limb.
<i>m.</i> ,	.	.	.	Intestine.
<i>n.</i> ,	.	.	.	Male copulative organ.
<i>o.</i> ,	.	.	.	Vas deferens.
<i>p.</i> ,	.	.	.	Heart.
<i>r.</i> ,	.	.	.	Eye.

2. Antennule of male.

3. ,, female (secondary branch abnormal).

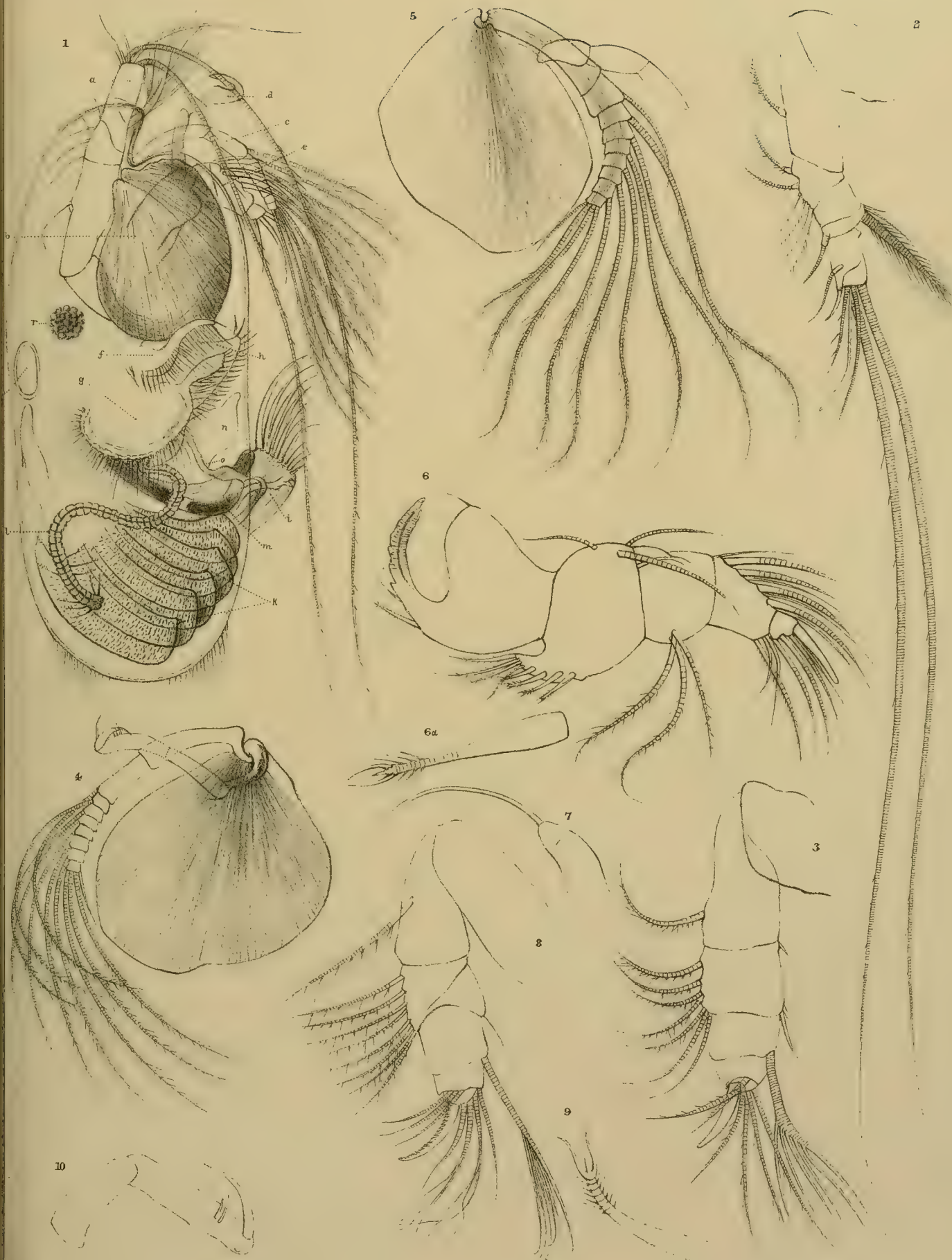
4. Antenna of male.

5. ,, female.

6. Mandibular foot of female. 6*a*. One of the tridentate setæ more highly magnified.

### *Asterope teres.*

7. Secondary branch of antenna of female.
8. Antennule of female.
9. Seta of mandibular foot.
10. Secondary branch of antenna of male.



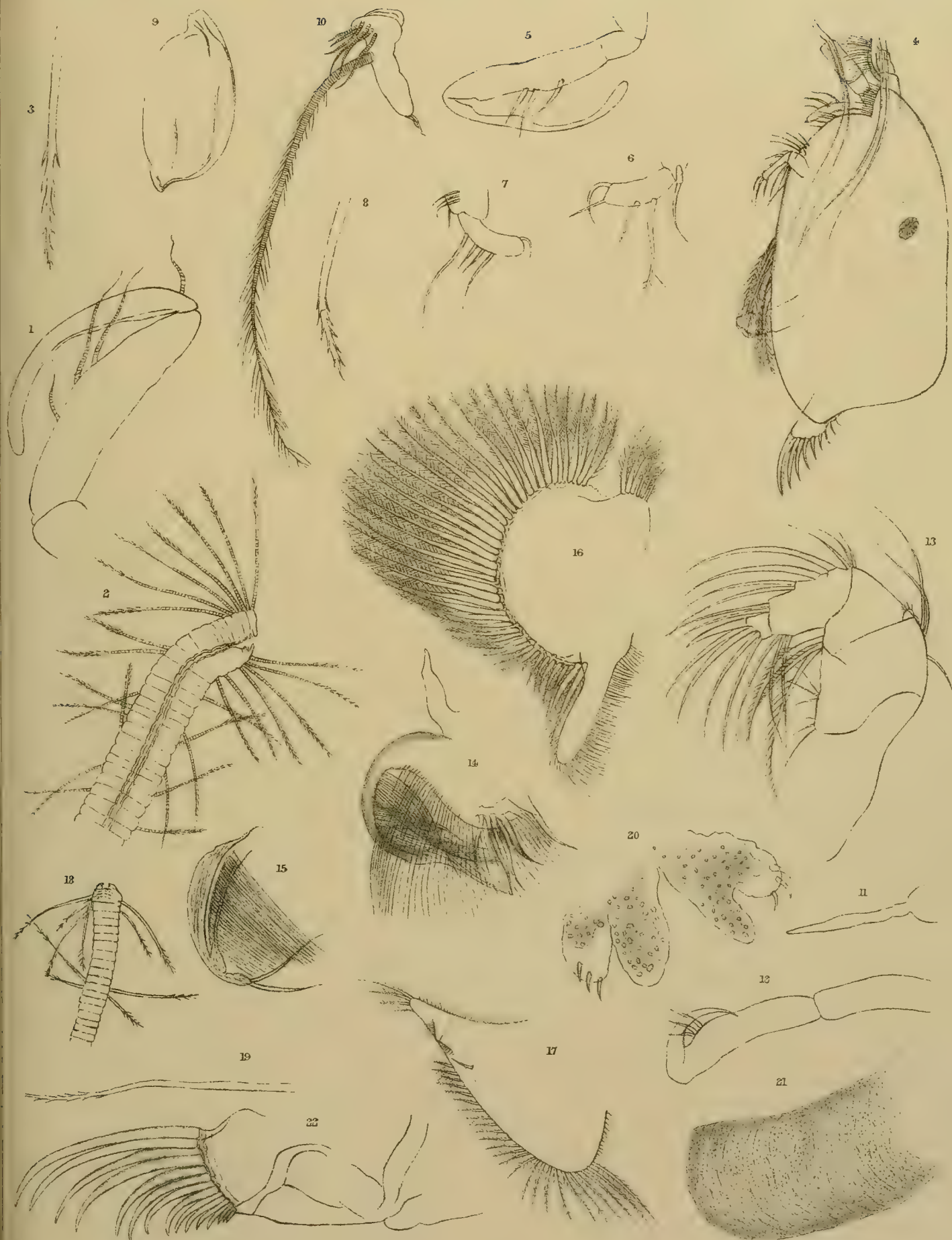


EXPLANATION OF PLATE LI.

## P L A T E   L I.

### Figure

1. *Philomedes brenda*, male, secondary branch of antenna.
2.     ,,         ,,         vermiform appendage.
3.     ,,         ,,         spine of vermiform appendage.
4.     ,,         *Lilljeborgii*, male, seen from left side.   × 30.
5.     ,,         ,,         ,,         secondary branch of antenna.
6.     ,,         ,,         female, secondary branch of antenna.
7.     ,,         *Macandrei*, female, secondary branch of antenna.
8.     ,,         ,,         spine of vermiform limb.
9.     ,,         *Folini*, male, seen from left side.   × 16.
10.    ,,         ,,         female, secondary branch of antenna.
11. *Asterope maricæ*, male, frontal tentacle.
12.    ,,         ,,         ,,         secondary branch of antenna.
13.    ,,         ,,         ,,         mandibular foot.
14.    ,,         ,,         maxilla of first pair.
15.    ,,         ,,         distal portion of same.
16.    ,,         ,,         maxilla of second pair.
17.    ,,         ,,         ,,         third pair.
18.    ,,         ,,         portion of vermiform limb.
19.    ,,         ,,         spine of same more highly magnified.
20.    ,,         ,,         copulatory organs.
21.    ,,         ,,         one of the branchial laminæ.
22.    ,,         ,,         caudal laminæ.



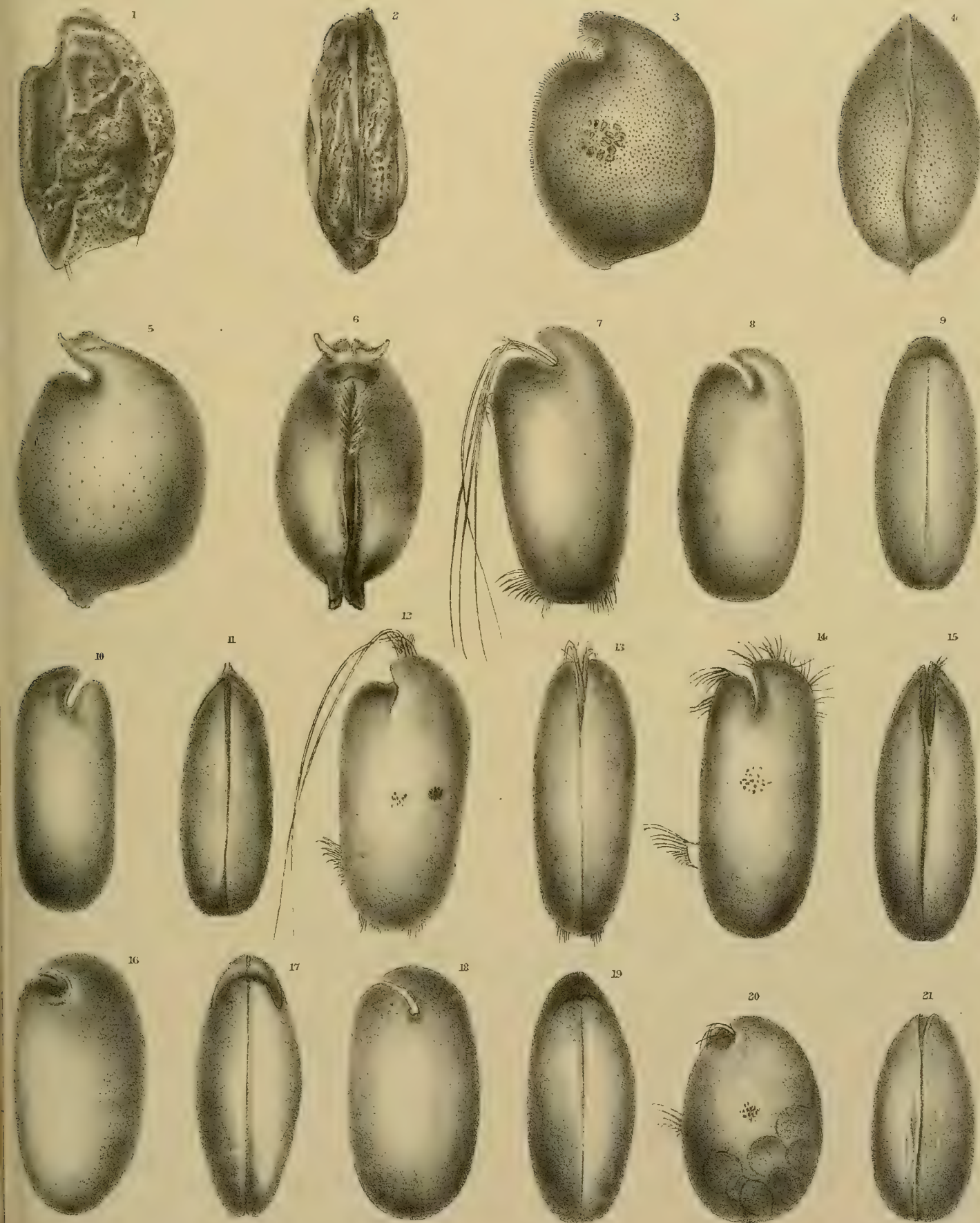


EXPLANATION OF PLATE LII.

## PLATE LII.

Figure

1.	<i>Nematohamma obliqua</i> , seen from left side,	.	.	.	.	× 40.
2.	„ „ „ „ above,	.	.	.	.	× 40.
3.	<i>Philomedes Lilljeborgii</i> , female, seen from left side,	.	.	.	.	× 25.
4.	„ „ „ „ „ above,	.	.	.	.	× 25.
5.	„ <i>Macandrei</i> , „ „ „ left side,	.	.	.	.	× 25.
6.	„ „ „ „ „ below,	.	.	.	.	× 25.
7.	<i>Asterope norvegica</i> , male, seen from left side,	.	.	.	.	× 25.
8.	„ „ female, „ „ „	.	.	.	.	× 25.
9.	„ „ „ „ „ below,	.	.	.	.	× 25.
10.	„ <i>mariaæ</i> , small specimen, seen from right side,	.	.	.	.	× 25.
11.	„ „ male, seen from below,	.	.	.	.	× 25.
12.	„ „ male, „ „ left side,	.	.	.	.	× 25.
13.	„ „ „ „ „ below,	.	.	.	.	× 25.
14.	„ „ female, „ „ left side,	.	.	.	.	× 20.
15.	„ „ „ „ „ below,	.	.	.	.	× 20.
16.	„ <i>elliptica</i> , „ „ „ left side,	.	.	.	.	× 30.
17.	„ „ „ „ „ below,	.	.	.	.	× 30.
18.	„ <i>abyssicola</i> , „ „ „ left side,	.	.	.	.	× 30.
19.	„ „ „ „ „ below,	.	.	.	.	× 30.
20.	„ <i>teres</i> , „ „ „ left side,	.	.	.	.	× 35.
21.	„ „ „ „ „ below,	.	.	.	.	× 35.





EXPLANATION OF PLATE LIII.

## PLATE LIII.

*Crossophorus imperator*, female.

Figure

1. Left valve, seen from side.  $\times 12$ .
2. Antennule.
3. Secondary branch of antenna.
4. Mandibular foot; *a*, one of the masticating spines more highly magnified.
5. Maxilla of first pair.
6. „ second pair; *a*, *b*., ungues more highly magnified.
7. „ third pair.
8. Apex of vermiform limb.
9. One of the lateral setæ of the same.
10. Caudal lamina.
11. Secondary branch of antenna of male. (Copied from Report of "Challenger" Expedition.)

*Nematohamma obliqua*.

12. Antennule.
13. Secondary branch of antenna.
14. Mandibular foot.
15. Caudal lamina and copulatory organ.



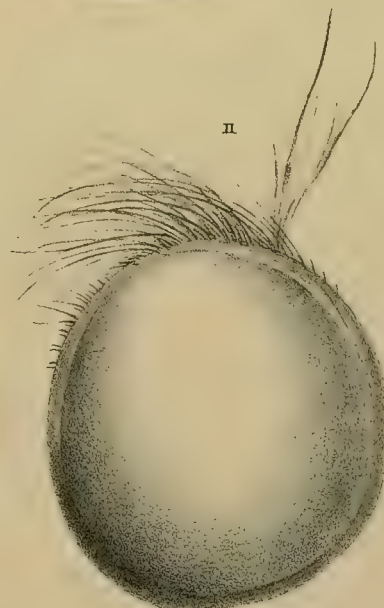
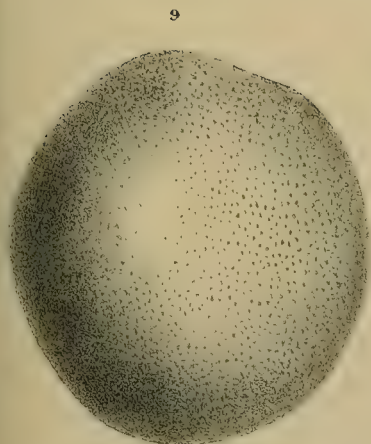
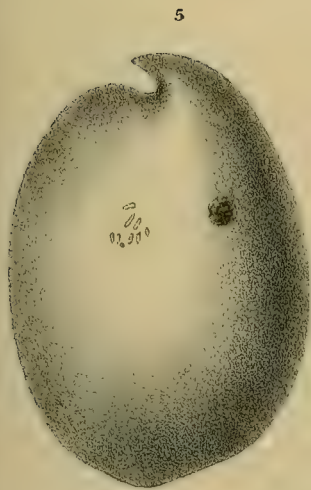
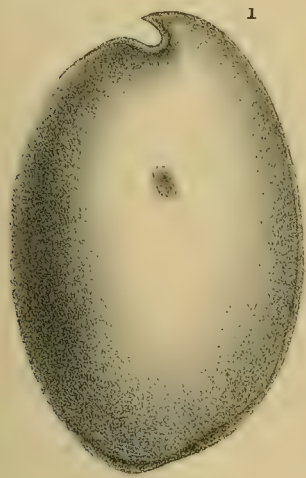


EXPLANATION OF PLATE LIV.

## PLATE LIV.

Figure

1.	<i>Cypridina mediterranea</i> , seen from left side,	.	.	.	.	× 22.
2.	„ „ „ „ below,	.	.	.	.	× 22.
3.	„ „ „ „ left side,	.	.	.	.	× 22.
4.	„ „ „ „ above,	.	.	.	.	× 22.
5.	„ <i>megalops</i> , „ „ left side,	.	.	.	.	× 25.
6.	„ „ „ „ below,	.	.	.	.	× 25.
7.	„ <i>norvegica</i> , „ „ left side,	.	.	.	.	× 16.
8.	„ „ „ „ below,	.	.	.	.	× 16.
9.	<i>Polycope orbicularis</i> , „ „ right side,	.	.	.	.	× 84.
10.	„ „ „ „ above,	.	.	.	.	× 84.
11.	<i>Polycopsis compressa</i> , „ „ left side,	.	.	.	.	× 84.
12.	„ „ „ „ above,	.	.	.	.	× 84.





EXPLANATION OF PLATE LV.

## PLATE LV.

*Cypridina mediterranea*, female.

Figure

1. Antennule; (*a*) eye.
2. Portion of eye more highly magnified.
3. Terminal joints of antennule and portions of setæ more highly magnified.
4. Antenna.
5. Base of an antennal seta, with spine.
6. Mandibular foot.
7. Maxilla of first pair.
8. „ second pair.
9. „ third pair.
10. Extremity of vermiform limb.
11. Caudal lamina.

*Polycope orbicularis*, female.

12. Animal seen from left side; left valve removed.
13. Mandible and palp.
14. Second maxilla, with branchial lamina.
15. Branchial lamina of the same, separated.
16. One of the caudal laminæ.



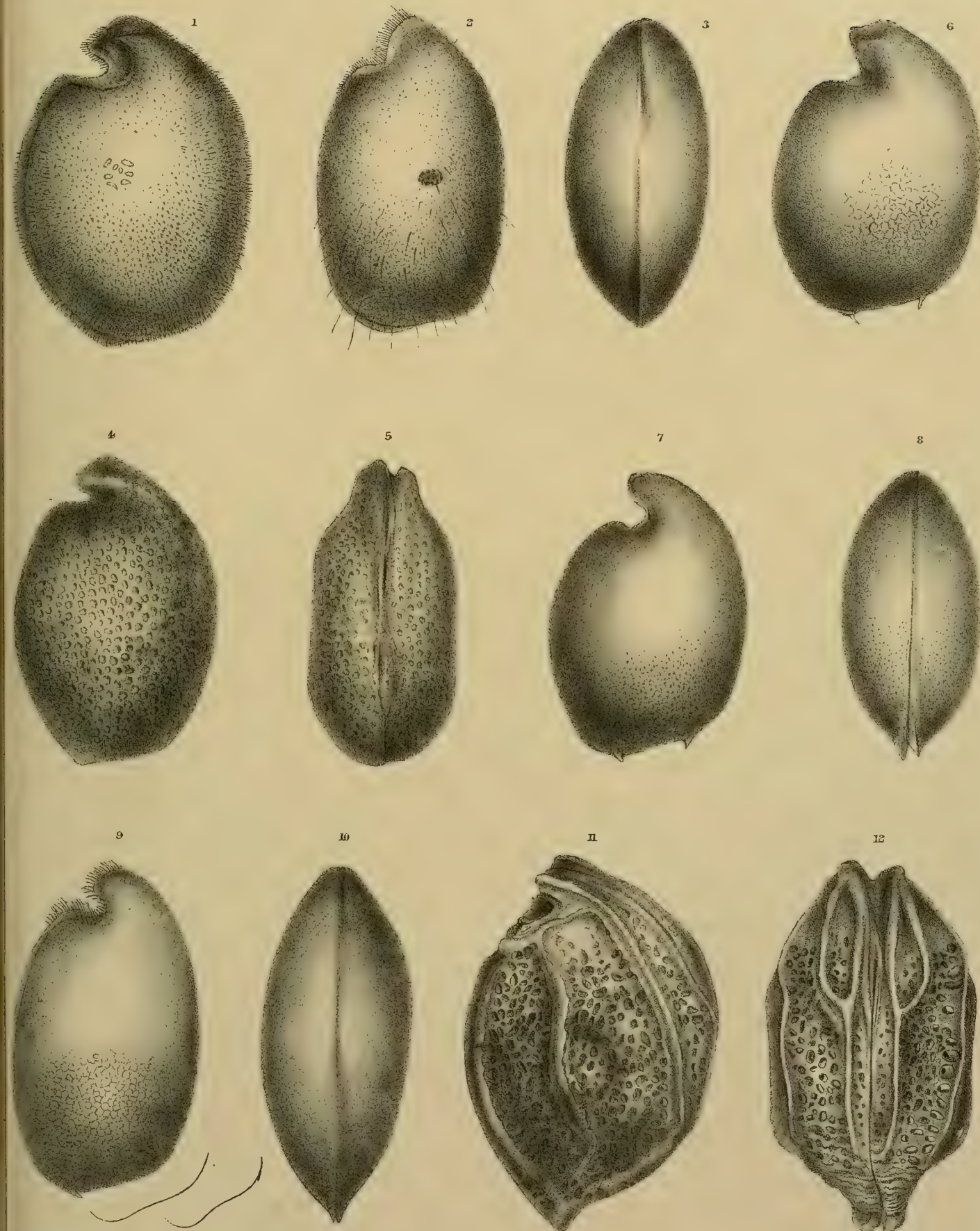


EXPLANATION OF PLATE LVI.

## PLATE LVI.

Figure

1.	<i>Philomedes brenda</i> , female, seen from left side,	.	.	.	.	.	.	×	25
2.	„ „ male, „ „ „ „	.	.	.	.	.	.	×	25
3.	„ „ „ „ above,	.	.	.	.	.	.	×	25
4.	„ <i>foveolata</i> , seen from left side,	.	.	.	.	.	.	×	40
5.	„ „ „ „ above,	.	.	.	.	.	.	×	40
6.	„ <i>interpuncta</i> , female, seen from left side (Loch Long),	.	.	.	.	.	.	×	50
7.	„ „ „ „ „ „ „ (Fosse de Cap Breton),	.	.	.	.	.	.	×	40
8.	„ „ male, „ „ „ „ (Cumbræ),	.	.	.	.	.	.	×	40
9.	„ „ „ „ „ above,	.	.	.	.	.	.	×	40
10.	„ <i>Folini</i> , female, seen from left side,	.	.	.	.	.	.	×	32
11.	„ „ „ „ „ above,	.	.	.	.	.	.	×	32





EXPLANATION OF PLATE LVII.

## PLATE LVII.

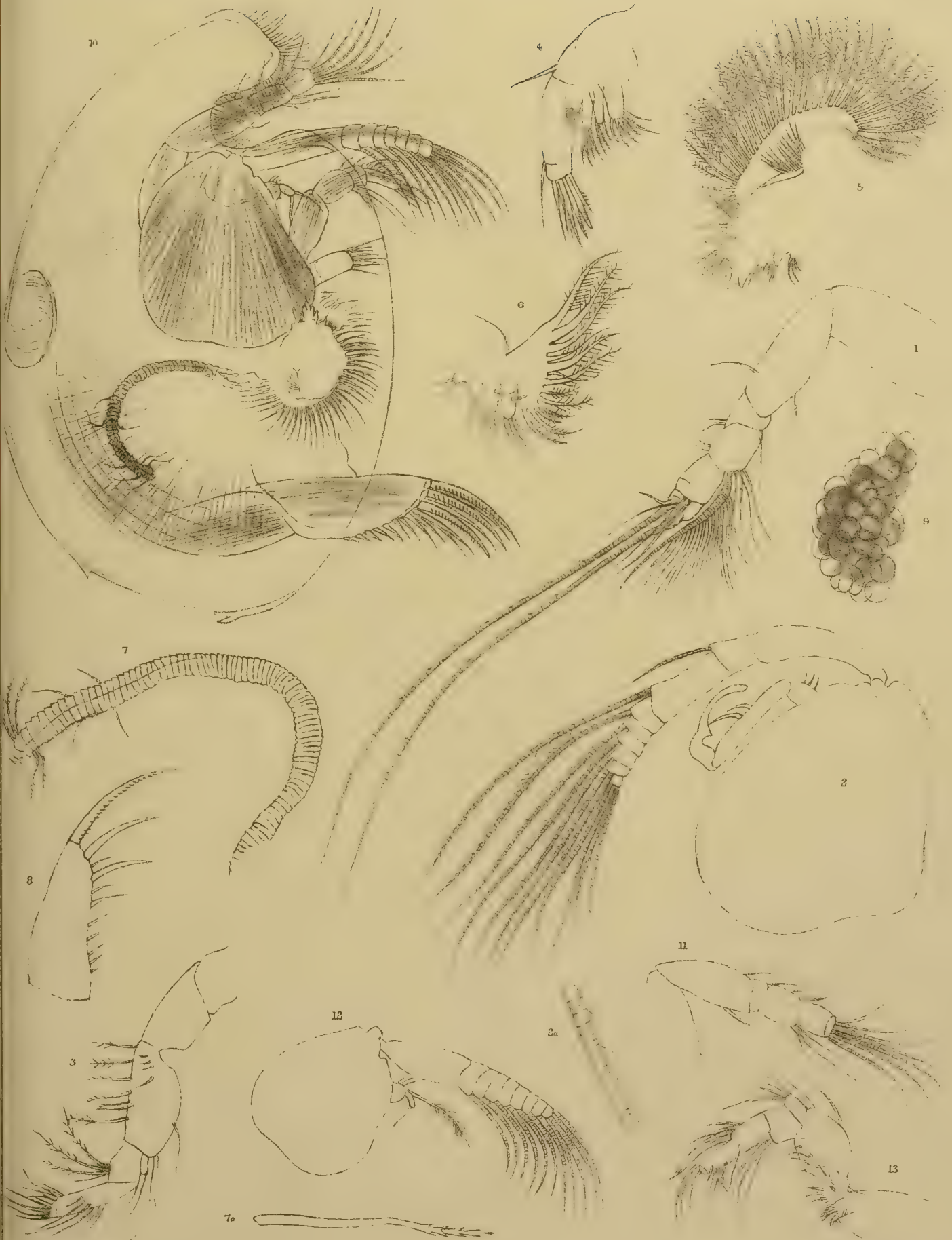
*Philomedes interpuncta*, male.

Figure

1. Antennule.
2. Antenna. 2 (*a*) Portion of first antennal seta.
3. Mandibular foot.
4. Maxilla of first pair.
5. „ second pair
6. „ third pair.
7. Vermiform limb. 7 (*a*) Spine of same more highly magnified.
8. Caudal lamina.
9. Eye.

*Philomedes interpuncta*, female.

10. Animal seen from right side; right valve removed.
11. Antennule.
12. Antenna.
13. Mandibular foot.





EXPLANATION OF PLATE LVIII.

## PLATE LVIII.

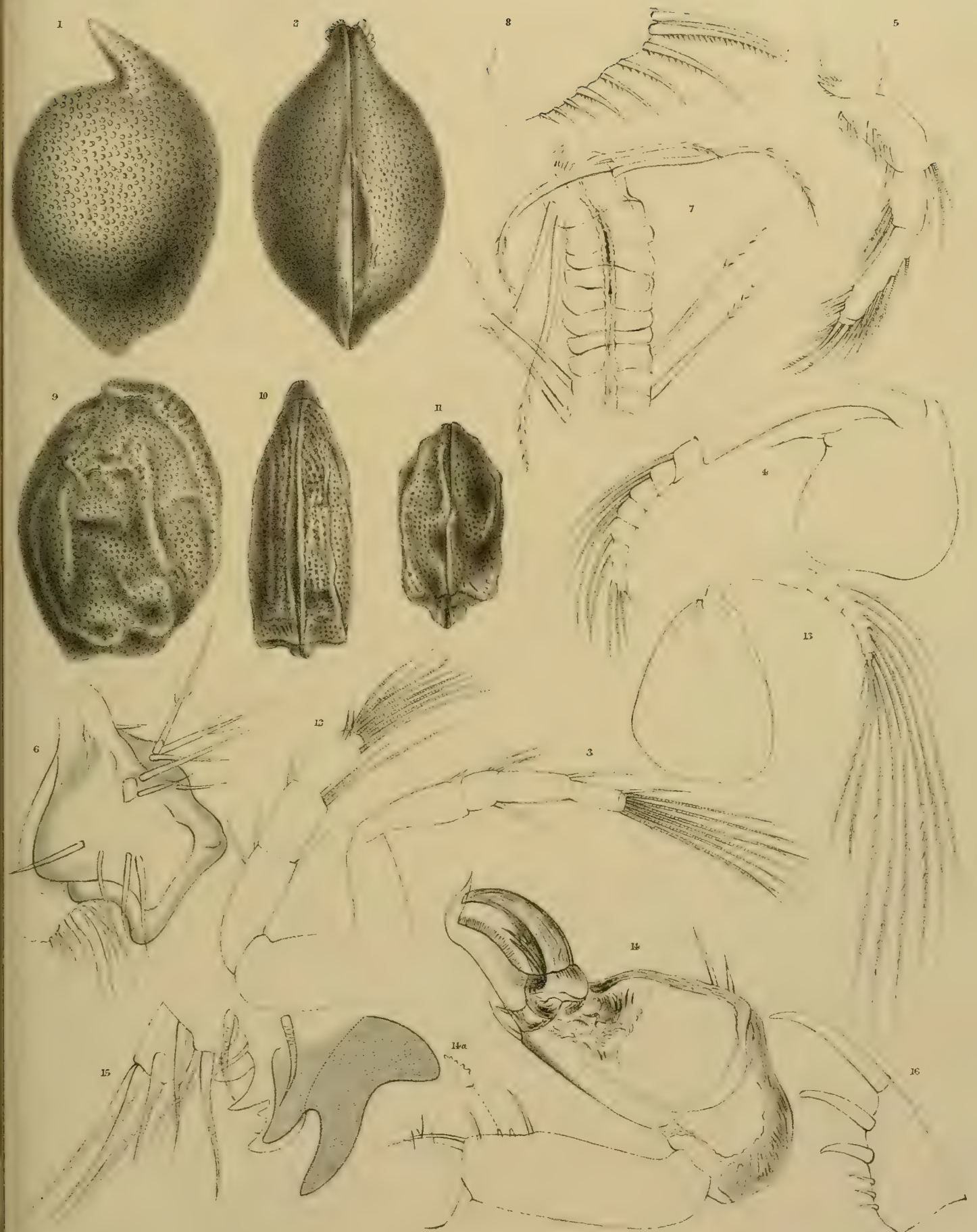
*Tetragonidon ctenorhynchus*, female.

Figure

1. Shell, seen from left side,  $\times 30$ .
2. „ „ „ above,  $\times 30$ .
3. Antennule.
4. Antenna.
5. Mandibular foot.
6. Outer tooth of second maxilla.
7. Apex of vermiform limb.
8. Caudal lamina.

*Rutiderma compressa*, female.

9. Shell, seen from left side,  $\times 40$ .
10. „ „ „ above,  $\times 40$ .
11. „ „ „ front,  $\times 40$ .
12. Antennule.
13. Antenna.
14. Mandibular foot. (*a*) One of the spines of the second joint more highly magnified.
15. Teeth and setæ of second maxilla.
16. Caudal lamina.





EXPLANATION OF PLATE LIX.

## PLATE LIX.

### *Paramekodon inflatus*, female.

#### Figure

1. Shell, seen from left side,  $\times 30$ .
2. „ „ „ above,  $\times 30$ .
3. Antennule. (a) Portion of a sensory filament more highly magnified.
4. Secondary branch of antenna.
5. Mandible and palp.
6. Maxilla of first pair. (a) One of the shorter spines more highly magnified.
7. „ second pair.
8. Teeth of the same more highly magnified.
9. Maxilla of third pair.
10. Caudal am

### *Streptoleberis rectirostris*.

11. Shell, seen from left side,  $\times 30$ .
12. „ „ „ above,  $\times 30$
13. „ „ „ behind  $\times 30$ .

### *Tetragonodon erinaceus*.

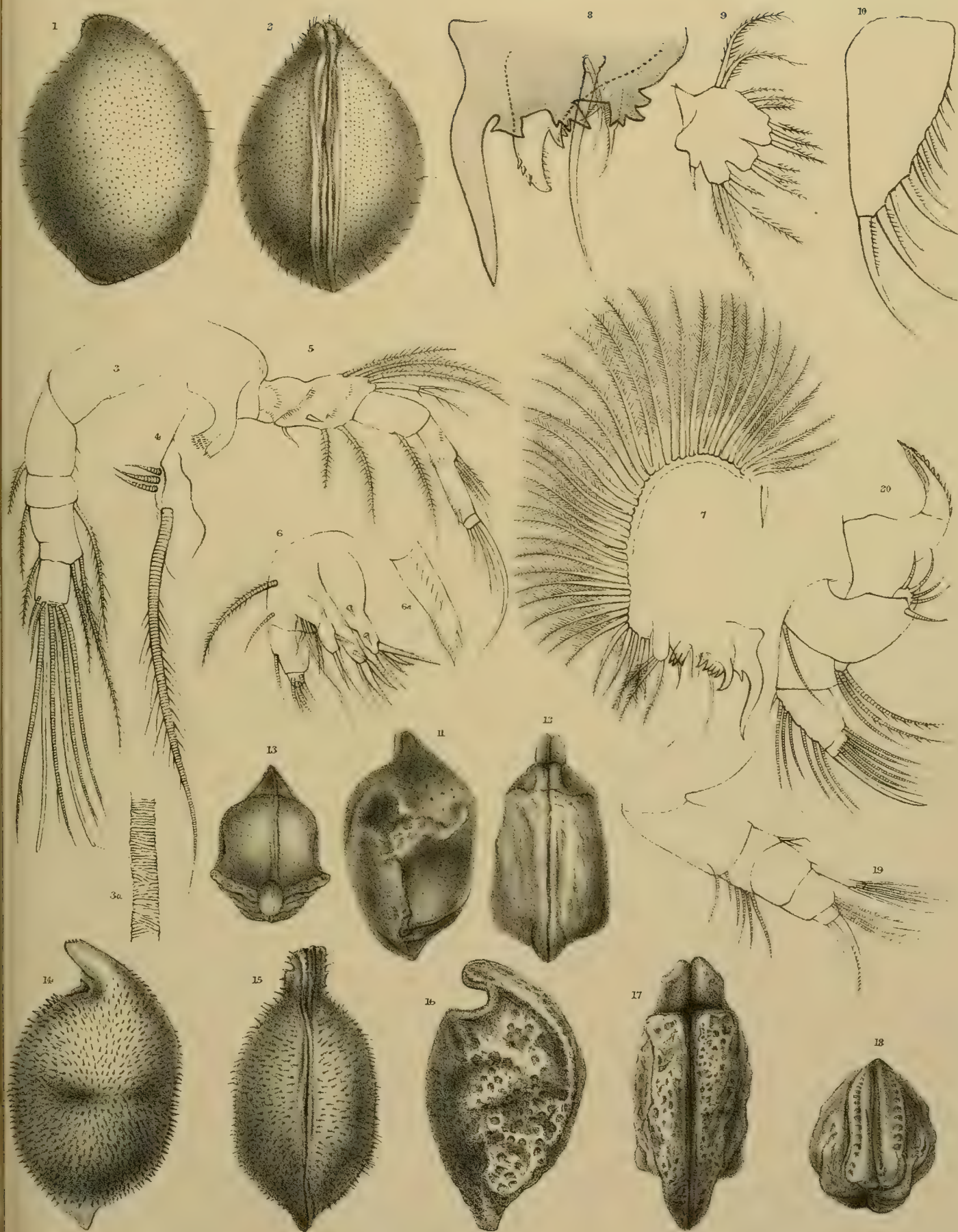
14. Shell, seen from left side,  $\times 30$ .
15. „ „ „ above,  $\times 30$ .

### *Streptoleberis favosa*.

16. Shell, seen from left side,  $\times 40$ .
17. „ „ „ below, „
18. „ „ „ front, „

### *Asterope elliptica*.

19. Antennule of female.
20. Mandibular foot of female.





EXPLANATION OF PLATE LX.

# PLATE LX.

## *Sarsiella capsula*, female.

Figure

1. Shell, seen from left side, . . . . . × 40.
2. „ „ „ above, . . . . . × 40.
3. „ „ „ below, . . . . . × 40.
4. „ „ „ behind, . . . . . × 40.
18. First maxilla.

## *Sarsiella globulus*, female.

5. Shell, seen from left side, . . . . . × 30.
6. „ „ „ below, . . . . . × 30.
7. „ „ „ front, . . . . . × 30.
8. Antennule.
9. Appendicular branch of the antenna.
10. Mandibular foot.
11. First maxilla.
12. One of the spines of first maxilla.
13. Second maxilla.
14. Vermiform limb, apex.
15. „ „ one of the spines.
16. „ „ chitinous bands.
17. Caudal lamina.

## *Cypridina norvegica*, male.

19. Terminal joints of antennule with setæ.
20. Spine of antennule, with suctorial disc.
21. One of the disc-bearing setæ of antennule.

## *Conchæcia spinirostris*, male.

22. Armature of the principal seta of antennule.

## *Conchæcia elegans*, male.

23. Armature of the principal seta of antennule.





EXPLANATION OF PLATE LXI.

## PLATE LXI.

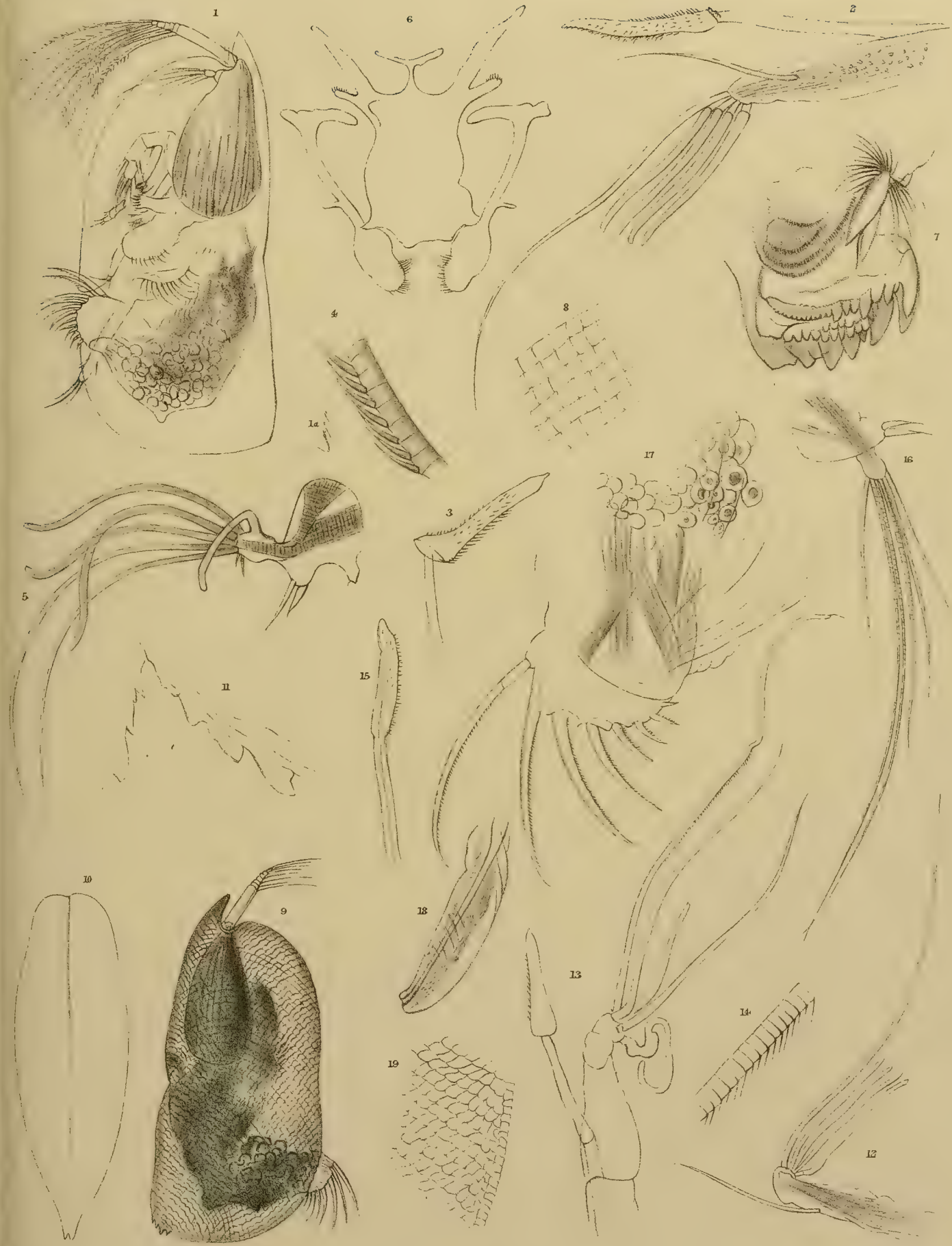
### *Conchæcia maxima.*

#### Figure

1. Female, seen from left side, left valve removed,  $\times 23$ . (a) Teeth of postero-dorsal angle of shell of male.
2. Antennule and frontal tentacle of female.
3. End of frontal tentacle of male.
4. Portion of seta of antennule of male, showing marginal spines.
5. Secondary branch of antenna of male.
6. Labrum, labium, &c.
7. End of mandible of male.
8. Reticulation of shell.

### *Conchæcia borcalis.*

9. Female, seen from right side,  $\times 34$ .
10. „ in outline, seen from above.
11. Teeth of postero-dorsal angle.
12. Antennule of female.
13. „ „ male.
14. Spinous portion of anterior antennular seta of male.
15. Frontal tentacle of female.
16. Secondary branch of antenna, female.
17. Caudal lamina and ovaries.
18. Copulatory organ of male.
19. Shell structure.





EXPLANATION OF PLATE LXII.

## PLATE LXII.

### *Conchæcilla lacerta* (male).

#### Figure

1. Antennule and frontal tentacle.
2. Part of principal seta of antennule, with marginal cilia, more highly magnified.
3. Base of secondary branch of antenna.
4. Apical portion of mandible.

### *Conchæcia magna*.

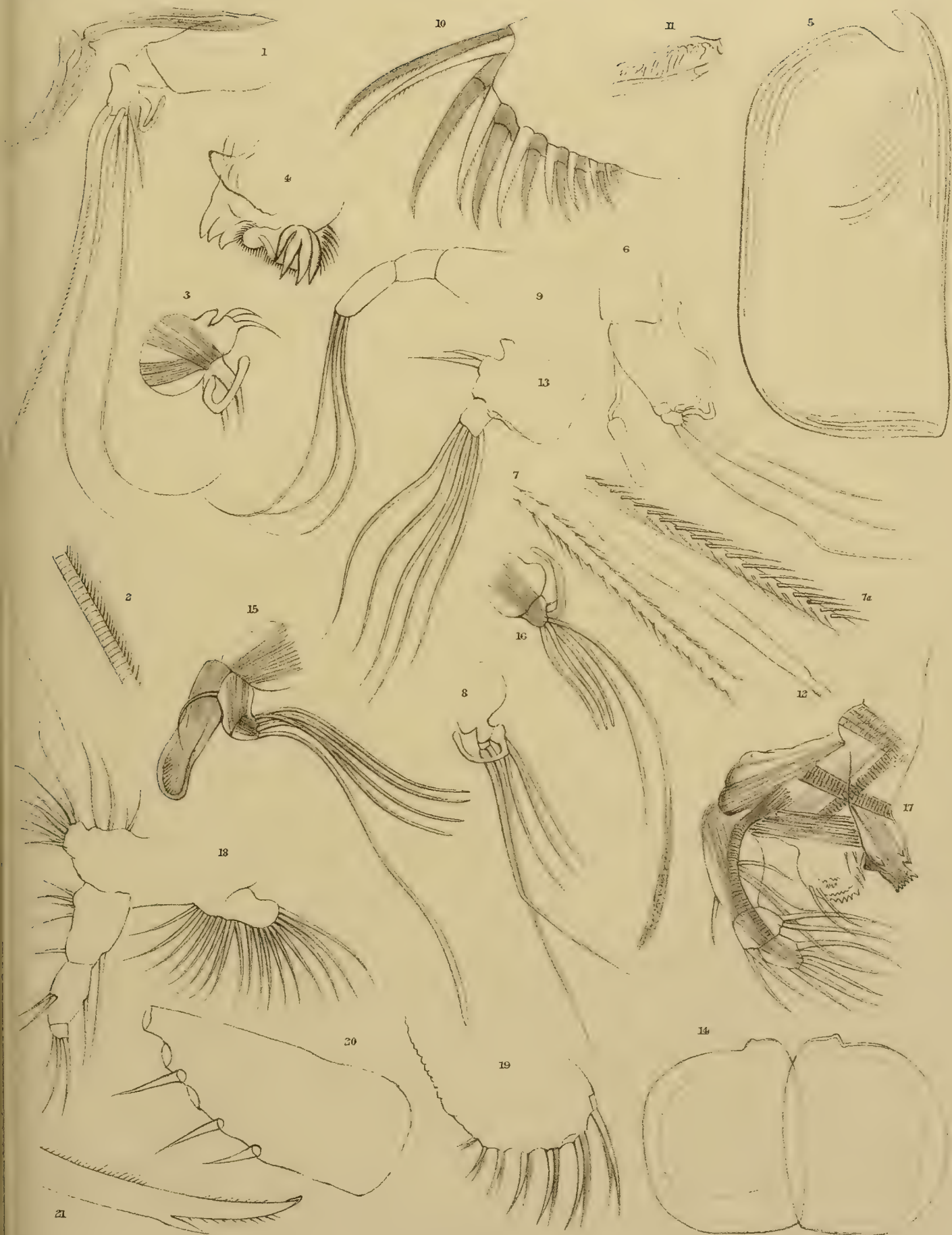
5. Shell of male, seen from left side,  $\times 84$ .
6. Antennule and frontal tentacle of male.
7. Part of principal seta of same, more highly magnified.
- 7a. „ „ „ „ seen from side.
8. Secondary branch of antenna of male.
9. Foot of first pair (male).
10. Caudal lamina
11. Copulatory organ of male.
12. End of frontal tentacle, female.
13. Secondary branch of antenna, female.

### *Halocypris concha* (male).

14. Shell; valves open and seen from within,  $\times 24$ .
15. Frontal tentacle and antennule.
16. Secondary branch of antenna.
17. Mandible and palp.
18. Maxilla of first pair, with appendage.
19. Caudal lamina.

### *Streptoleberis javosa*.

20. An imperfect caudal lamina.
21. One of the ungues of the same.





EXPLANATION OF PLATE LXIII.

# PLATE LXIII.

## *Conchæcia obtusata.*

Figure

1. Shell of female, seen from right side, × 40.
2. „ „ „ „ below, × 40.

## *Microconchæcia Clausii.*

3. Shell of female, seen from right side, × 80.
4. Mandibular plates of same.
5. Antennule and frontal tentacle of male.
6. Armature of principal antennular seta, male.
7. Antennule and frontal tentacle, female.
8. Secondary branch of antenna, male.
9. Copulatory organ of male.

## *Paradoxostoma affine.*

10. Shell, seen from left side, × 100.
11. „ „ „ „ above, × 100.

## *Paradoxostoma inflexum.*

12. Shell, seen from left side, × 100.
13. „ „ „ „ above, × 100.

## *Cythere semiovata.*

14. Shell, seen from left side, × 100.
15. „ „ „ „ above, × 100.

## *Cytherura bodotria.*

16. Shell, seen from left side, × 100.
17. „ „ „ „ above, × 100.

## *Cytherura mucronata.*

18. Shell, seen from left side, × 80.
19. „ „ „ „ above, × 80.

## *Cytherura cornuta.*

20. Outline of shell (young), seen from left side, × 120.

## *Cytherura nigrescens.*

21. Outline of shell (young), seen from left side, × 120.

## *Ilyocypris Bradii.*

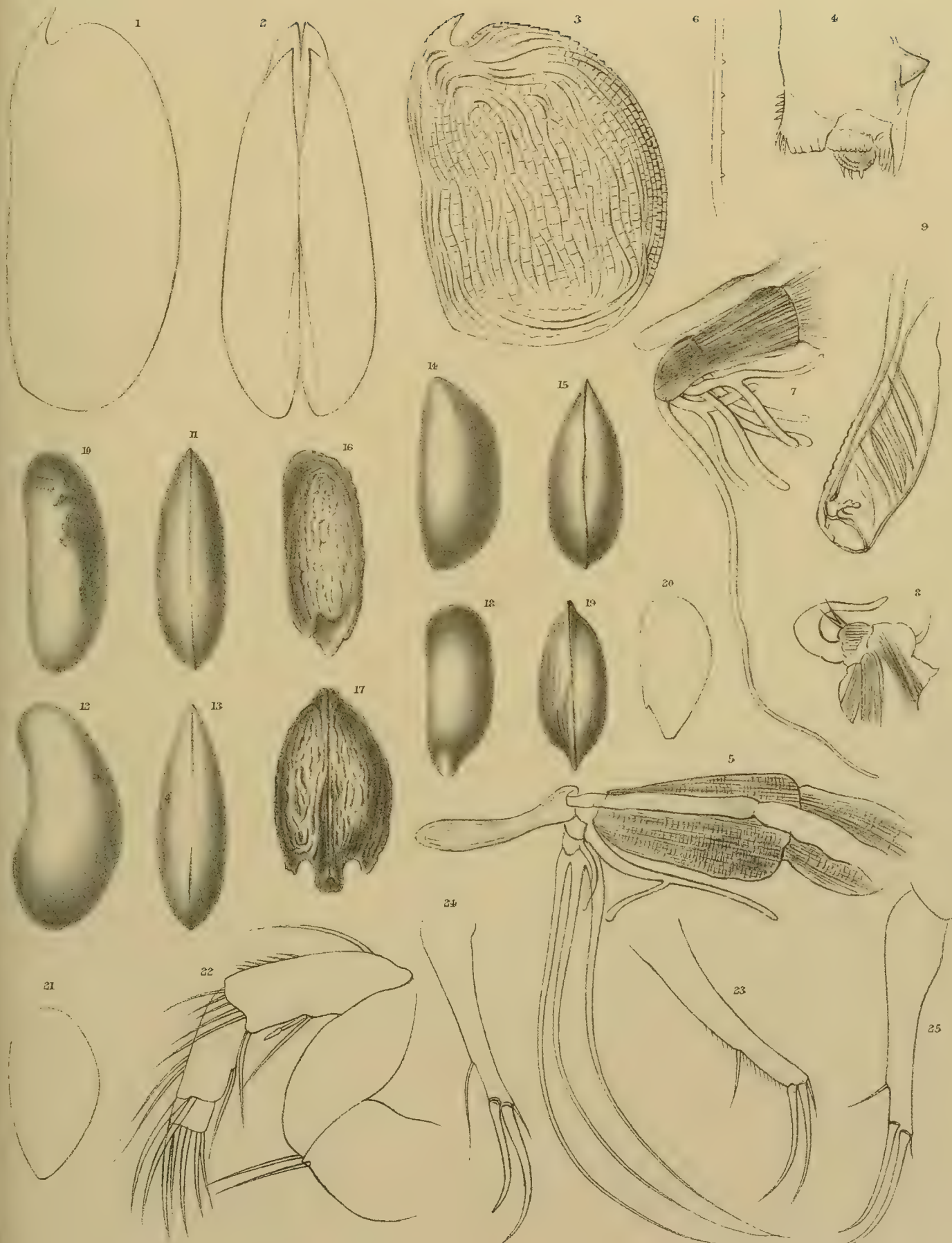
22. Antennule.
23. One of the caudal rami.

## *Candona pubescens.*

24. One of the caudal rami.

## *Candona Zenkeri.*

25. One of the caudal rami.





EXPLANATION OF PLATE LXIV.

## PLATE LXIV.

### *Conchæcissa armata* (female?).

Figure

1. Shell, valves open,  $\times 25$ .
2. Reticulation of anterior margin of shell, more highly magnified.
3. Frontal tentacle.
4. End of mandible of left side (?).
5. „ „ oblique view, right side (?).

### *Conchæcia Haddoni*.

6. Shell of female seen from left side,  $\times 40$ .
7. Reticulation of anterior margin of shell
8. „ of central portion of shell.
9. Capitulum of frontal tentacle of female.
10. „ „ „ male.
11. Labrum (upper lip).
12. Biting plate of mandible of female.
13. „ „ „ male.
14. Spinous armature of a part of the principal seta of antennule, ♂.
15. Secondary branch of the right antenna of male. (a) Apex of hooked process of the same.
16. One of the caudal laminæ.

### *Cypris incongruens* (male).

17. Second maxilla of left side.
18. Verticillate sac.

### *Pionocypris vidua*.

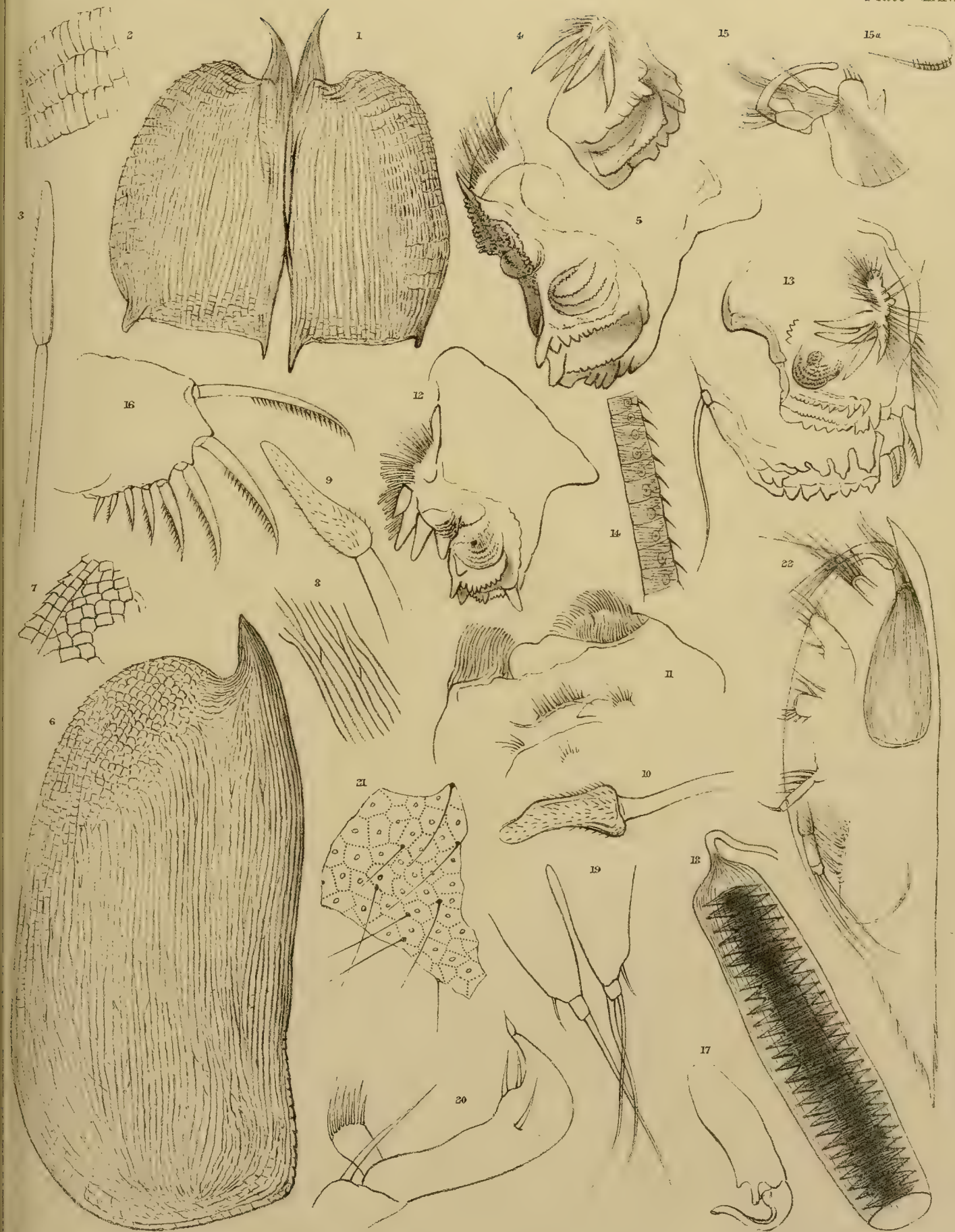
19. Caudal rami.

### *Candona pubescens*.

20. Second maxilla of ♂, right side.
21. Shell structure.

### *Conchæcilla daphnoides*.

22. Entire animal, seen from the left side. (Specimen taken off Achill Head, Ireland.)





EXPLANATION OF PLATE LXV.

## PLATE LXV.

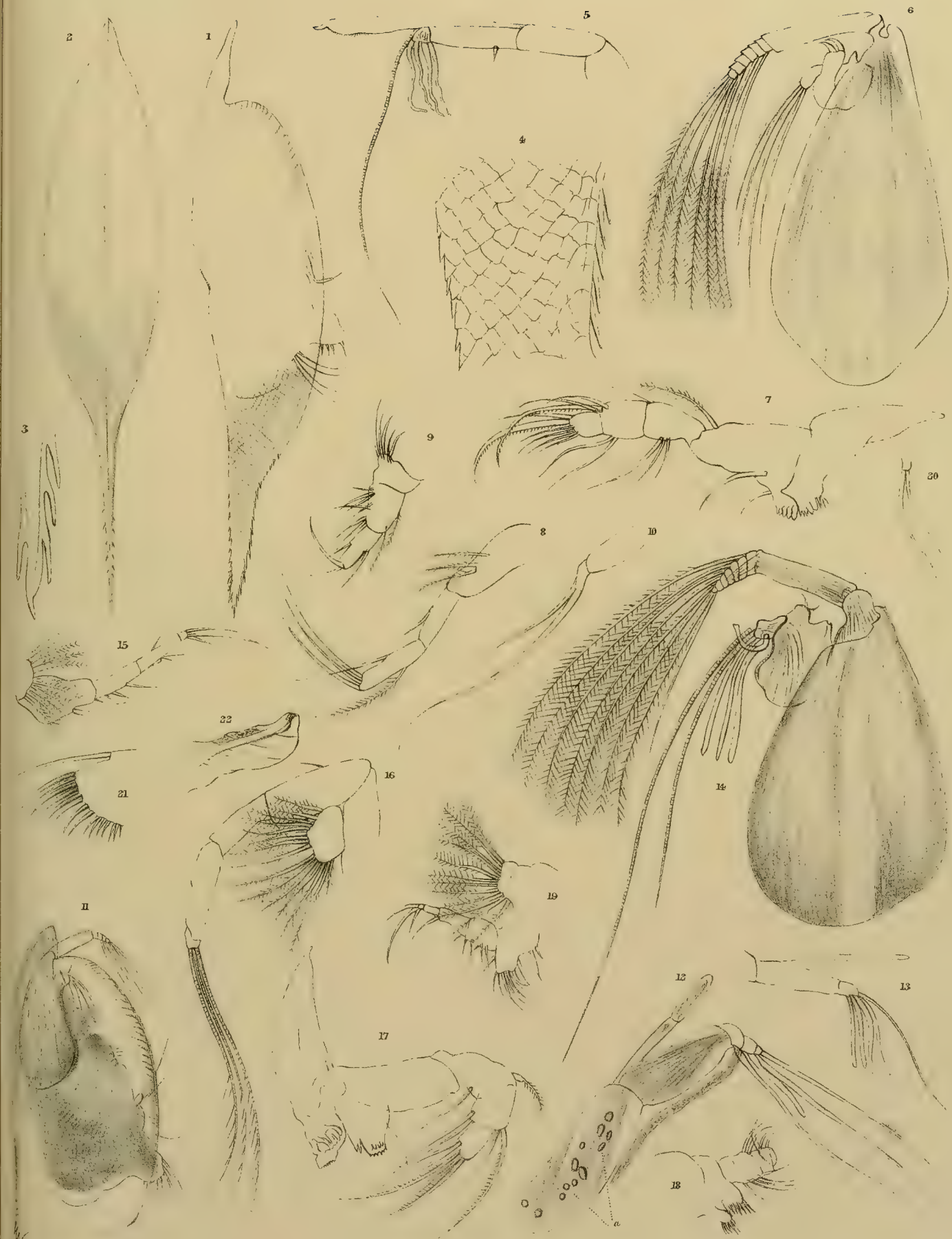
### *Conchæcilla lacerta.*

#### Figure

1. Shell, seen from right side,  $\times 25$ .
2. „ „ „ above,  $\times 25$ .
3. Posterior extremity of same, more highly magnified.
4. Shell structure near posterior extremity.
5. Frontal tentacle and antennule.
6. Antenna.
7. Mandible and palp.
8. Part of first foot.
9. First maxilla (distal portion).
10. Last foot.

### *Conchæcia elegans.*

11. Female, seen from right side,  $\times 40$
12. Frontal tentacle and antennule of male.
13. „ „ „ „ „ female.
14. Antenna of male.
15. First foot of female.
16. „ „ „ male.
17. Mandible of female.
18. Maxilla of first pair, female.
19. „ second pair, male.
20. Foot of last pair, male.
21. Caudal laminae.
22. Copulatory organ of male.





EXPLANATION OF PLATE LXVI.

## PLATE LXVI.

### *Cytherella abyssorum.*

#### Figure

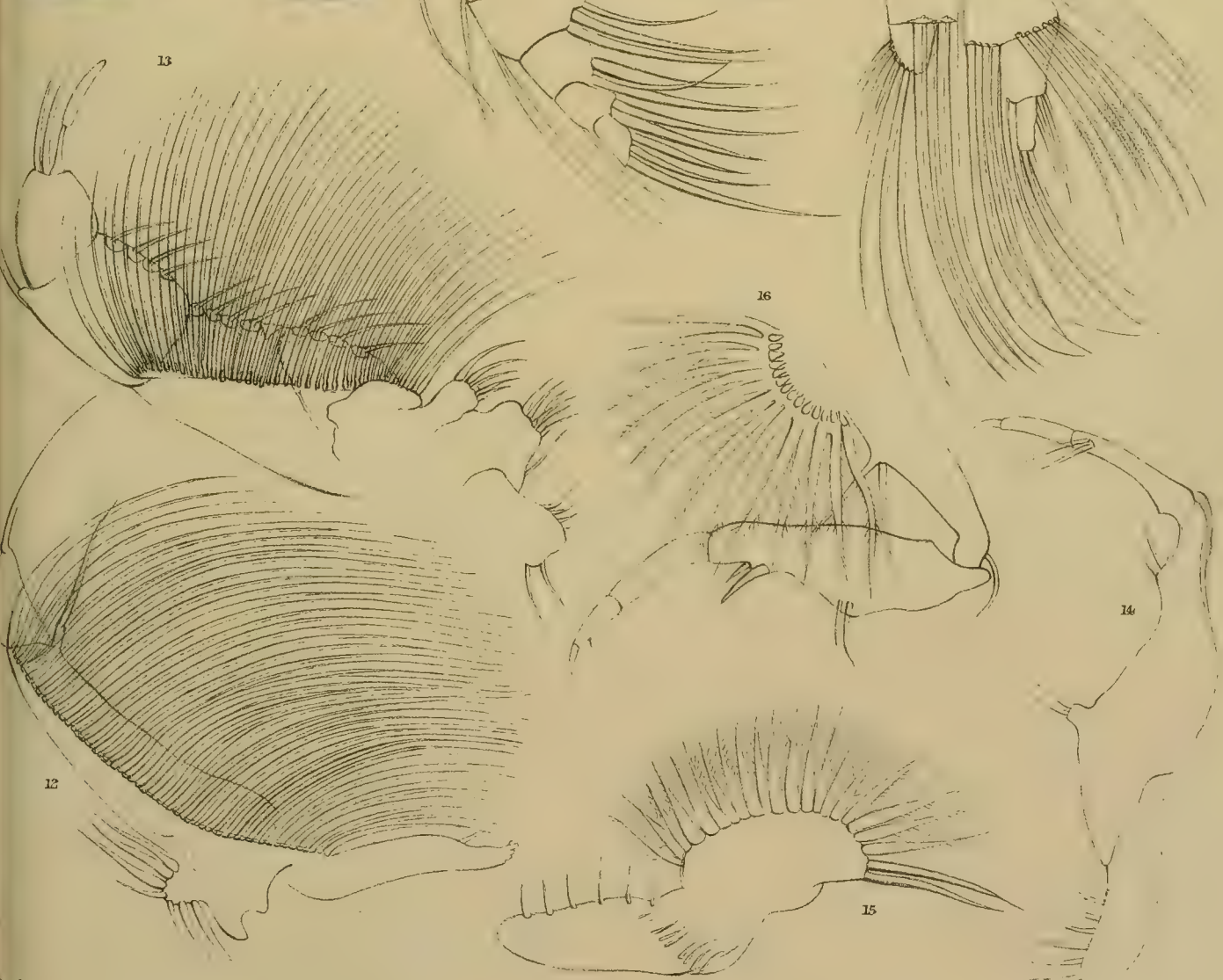
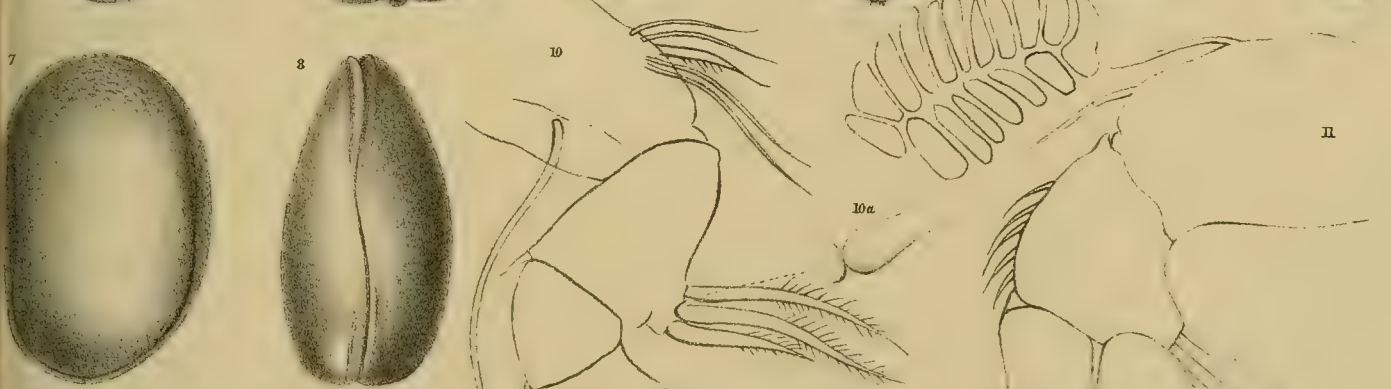
1. Shell of female, seen from left side,  $\times 50$ .
2.    "       "       "       "    above,  $\times 50$ .
15. Second maxilla, with branchial lamina (female).

### *Cytherella laevis.*

7. Shell of female, seen from left side,  $\times 40$ .
8.    "       "       "       "    above,  $\times 40$ .

### *Cytherella serrulata.*

3. Shell of female, seen from left side,  $\times 40$ .
4.    "       "       "       "    below,  $\times 40$  (with ova).
5. Shell of male, seen from left side,  $\times 40$ .
6.    "       "       "       "    above,  $\times 40$ .
9. Muscle-spots.
10. Antennule.
11. Antenna.
12. Mandible and palp.
13. First maxilla, female.
14. Second maxilla of male, without branchial lamina.
16. Third maxilla of male, with branchial lamina.





EXPLANATION OF PLATE LXVII.

## PLATE LXVII.

### *Polycope orbicularis* (female).

#### Figure

1. Antennule.
2. Antenna.
3. First maxilla.

### *Polycopsis compressa* (female).

4. Antennule and frontal cilia.
5. Mandible and palp.
6. Caudal lamina.
7. Teeth of anterior margin of shell,  $\times 200$ .
8. Sculpture of shell,  $\times 200$ .

### *Polycope punctata* (female).

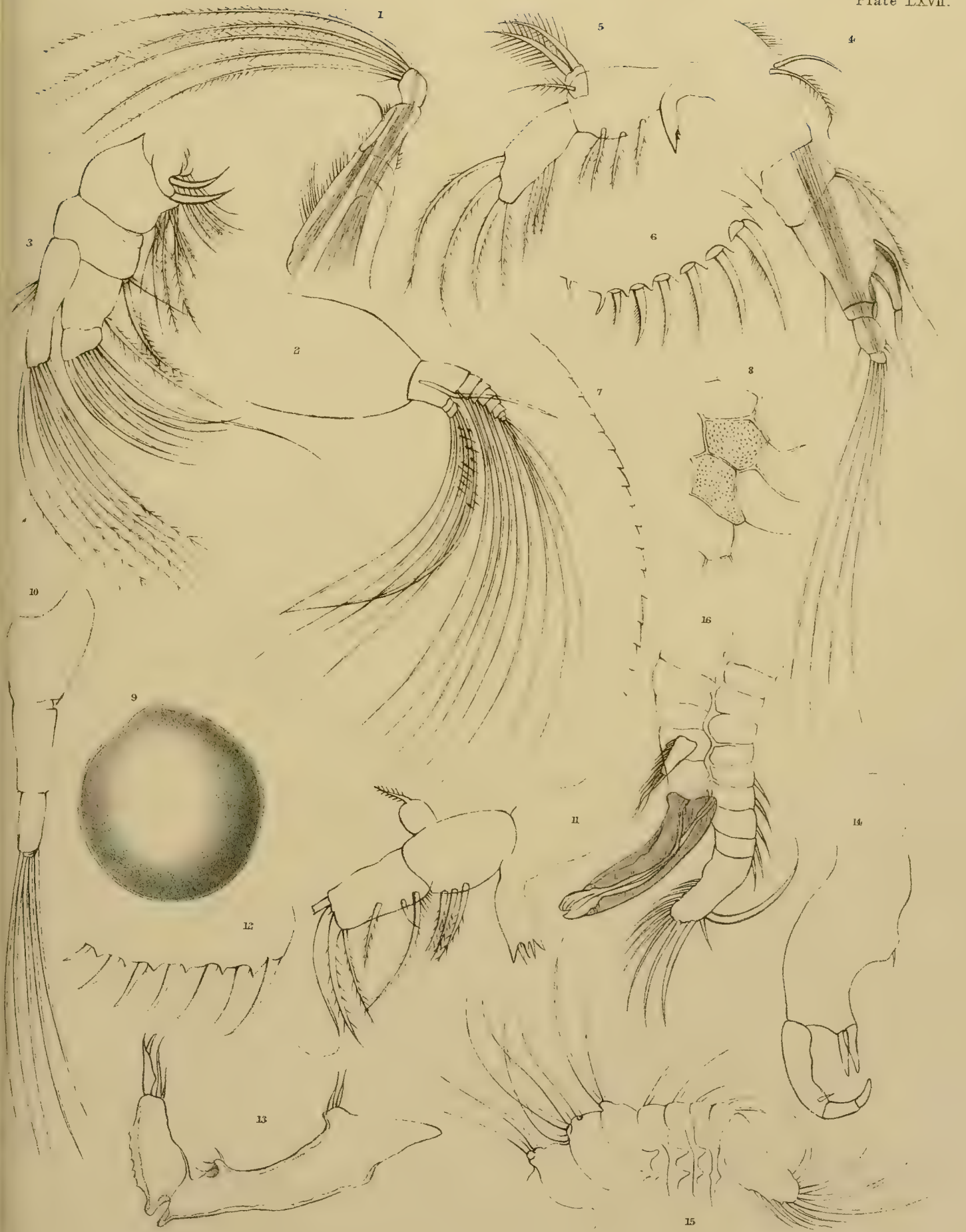
9. Shell, seen from left side,  $\times 60$ .
10. Antennule.
11. Part of mandible and palp (a seta broken).
12. Part of caudal lamina.

### *Cytherella abyssorum*.

13. Second maxilla, male.
14. Third       ,,       ,,

### *Cytherella serrulata*.

15. Abdomen and tail, female.
16.       ,,       with copulatory organ, male.





EXPLANATION OF PLATE LXVIII.

# PLATE LXVIII.

## *Candona glacialis.*

Figure

1. Shell of female, seen from left side, . . . . . x 30
2. " " " " above, . . . . . x 30

## *Cypria lacustris.*

3. Shell of female, seen from left side, . . . . . x 80
4. " " " " above, . . . . . x 80

## *Limnocythere inopinata (incisa, Sars).*

5. Shell of female, seen from left side, . . . . . x 84
6. " " " " above, . . . . . x 84

## *Candona pubescens.*

7. Shell of female, seen from left side, . . . . . x 55
8. " male, " " " " . . . . . x 55
9. " " " " above, . . . . . x 55

## *Cytheridea monensis.*

10. Shell, seen from left side, . . . . . x 84
11. " " " " above, . . . . . x 84

## *Candona Zenkeri.*

12. Shell of female, seen from left side, . . . . . x 56
13. " " " " above, . . . . . x 56

## *Candona stagnalis.*

14. Shell of female, seen from left side, . . . . . x 56
15. " " " " above, . . . . . x 56
16. " male, " " right side, . . . . . x 56
17. " " " " above, . . . . . x 56

## *Ilyocypris Bradii.*

18. Shell of female, seen from left side, . . . . . x 50
19. " " " " above, . . . . . x 50

## *Ilyocypris gibba.*

20. Shell of female, seen from left side, . . . . . x 50
21. " " " " above, . . . . . x 50

## *Cypria incongruens.*

22. Shell of male, seen from left side, . . . . . x 40
23. " " " " above, . . . . . x 40







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[JULY, 1896.]

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By PROFESSOR W. J. SOLLAS, LL.D., D.Sc., F.R.S.

(PLATE LXIX.)

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## XIII.

## A MAP TO SHOW THE DISTRIBUTION OF ESKERS IN IRELAND.

By PROFESSOR W. J. SOLLAS, LL.D., D.Sc., F.R.S.

(PLATE LXIX.)

(COMMUNICATED BY PERMISSION OF THE DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY.)

[Read FEBRUARY 20, 1895.]

**Introduction, Personal.**

IN the summer of 1893, my friend Mr. Praeger and I left Dublin for Maryborough to examine the remarkably fine esker which occurs near that town.\* The writings of Jukes had inspired us with the idea of the marine origin of eskers, and we were persuaded that it only required careful search to discover traces of marine organisms. We searched intently from early morning to late evening, but without success; not a trace of a shell rewarded our efforts, and this, notwithstanding the favourable character of much of the material composing the esker, which, from its fineness and somewhat argillaceous nature, was well fitted for the preservation of fossils, had these, at any time, been present.

This result, being in general harmony with that obtained by other investigators, will probably not be considered surprising; nor were we so much impressed by it, as by certain positive characters, which, although we had frequently seen eskers before, we now seemed to perceive for the first time. These were the definite form of the long narrow ridge, and, more particularly, the steepness of its slopes, and the looseness of its material, which evidently rested at an angle not far different from that of its angle of repose.

This single instance was in itself sufficient to dissipate all notions of a marine origin. We were already familiar with the fact that such ridges are nowhere known to be in process of formation by the sea at the present day; but we now perceived that the fact of loose material resting at approximately its angle of repose was incompatible with the idea of its deposition beneath the waters of a sea by means of currents.

The question that pressed itself for solution was this:—How could a ridge of

\* The northern part of this esker is shown within the southern border of Pl. LXIX., south of Mountmellick.

loose material have been deposited from water, as the structure of this one clearly proves it to have been, and yet have acquired such steeply sloping sides? The only answer that could be given was that, during deposition, boundary walls must have existed by which it was held up. What, then, were these walls? Might they not have been a lateral extension of the esker itself, a lateral extension so wide as to constitute an alluvial plateau? An answer in the affirmative has been given by at least one Irish geologist, Mr. M. Harrison;\* but such a solution has been rejected by others, including the late Professor Jukes, and as it seems to me on very sufficient grounds; for, in the first place, the existing drainage system of the country is not related to the eskers in a manner which would suggest such an explanation; and, in the next place, the structure of the eskers themselves is definitely opposed to it, since the stratified material of which they consist is frequently arranged so as to dip parallel to the sides of the ridge, and, in addition, the separate ridges sometimes unite so as to inclose deep hollows between them, which could not, by any possibility, have been excavated by a stream.†

It is impossible to explain an esker as the denuded remains of a plateau; and again we inquire what were the retaining walls which held it up during its deposition? Whatever they were, they no longer exist, and have utterly vanished from the face of the land. The only substance at all likely so to behave is ice. But we have independent evidence that the whole of Ireland was at one time buried under a system of confluent glaciers, and it is known that streams of water flow over, under, and through such ice-sheets. Let the channel of some such stream become choked up by *débris*, and a cast of it will be formed in sand, gravel, and pebbles, which, on the disappearance of the ice, might form a ridge in all respects similar to an esker.

If such an explanation were on the whole true, it would follow that an individual esker should resemble, in its wanderings over the country, the course of a river, it should branch and meander; and similarly a system of eskers, if such should exist, as might naturally be expected, should often repeat the characters of a river system. To see whether this was the case, I prepared from the published maps of the Geological Survey the maps which this Paper is written to illustrate, and on reference to it the resemblance, which we have deduced, will be manifest at a glance.

It is now clear why we did not succeed in finding marine shells at Maryborough; their absence is just what our present explanation would lead us to expect.

The next step was to acquire a knowledge of the literature of eskers; and from this it appears that a similar explanation to that we have just attained

\* M. Harrison: *On the Origin of Eskers*.—Proc. Belfast Field Club, ser. 2, vol. i., p. 100, 1875. In Sweden, this view had already been proposed by Törnebohm and others.

† Jukes' *Memoirs of the Geological Survey*, Nos. 98, 99, 108, 109, p. 8.

had already, over twenty years previously, been suggested by Professor N. H. Winchell in America, and by Dr. D. Hummel in Sweden in 1874.

If by the foregoing personal account I admit myself to have been twenty years behind the time, I willingly make the confession for the sake of what appears to me a fact of some interest, viz. that independent observers, studying eskers in three different countries, have been led independently, by personal investigation, to a fundamentally similar interpretation of these puzzling geographical features.

### Literature of the Subject.

Ridge-like hills, which owe their origin to glacial action, are of more than one kind, and it is necessary to distinguish between them. The first and most important step was taken by the Rev. Maxwell Close in 1865, who separated, under the name of "Drumlins," those ridges which consist of unstratified boulder clay from those formed of water-worn material. To these latter he restricted the term "Esker."\*

A further distinction has been suggested by Professor T. C. Chamberlin,† who proposes to divide eskers into two classes, the one containing those ridges that run with the slope of the ground—these he calls *âsar*—and the other, those that run transversely to the direction of the glacial movement, and which are usually associated with terminal moraines; these alone are to be called kames. The distinction may certainly be recognised in the case of Irish eskers, at least as regards their relation to the form of the ground or the movement of the ice; but not, so far as I am aware, as regards their association, or otherwise, with terminal moraines. In any case the term "esker" is too deeply rooted in the nomenclature of Irish geology for us to abandon it without inconvenience; possibly in Scotland greater readiness will be displayed in restricting the meaning of "kame."‡

\* *Notes on the General Glaciation of Ireland*, by the Rev. Maxwell H. Close (1865).—*Journ. Roy. Geol. Soc. of Ireland*, vol. i., p. 207, 1867.

† *The Terminal Moraine of the Second Glacial Epoch*.—Third Annual Report U.S. Geol. Survey, p. 300, 1883.

‡ On referring to Dr. J. Geikie's *Ice Age* (3rd edition), I find, however, that while the term "kame" is retained, it is proposed to abandon "esker" for "âs." On page 746 we find the following:—"As between the alternate terms 'âs' and 'esker,' the former has the sanction of priority, and is the local term for the great Scandinavian type. Notwithstanding this, the term esker is growing into favour among American Glacialists, doubtless for 'phonic reasons.'" I regret that I am unable to admit the priority of the term "âs" without further information. The series of esker-groups to be described later on is part of what was formerly called by the general name of Esker Riada. O'Donovan, in his translation of the *Annals of the Four Masters* at A.D. 123, where Esker Riada is mentioned, says of it—"This is a line of gravel hills extending from Dublin to Clarinbridge in the county of Galway. It is mentioned in ancient Irish MSS. as reaching from Dublin to Clonard, thence to Clonmacnois and Clonburren, and

Finally the late Professor Carvill Lewis has designated as marginal kames\* certain eskers in Pennsylvania which are associated with the terminal moraine, and which were formed by a subglacial drainage in the direction of the local valleys, but in the opposite direction to the flow of the ice.

The literature treating of the origin of eskers is very extensive; but we shall considerably shorten our account if we dispense, as we fairly may, with the treatment of those theories which invoke the action of the sea as a probable cause. Professor Carvill Lewis has, indeed, summarily dismissed such theories as “antiquated,” and they are certainly too well known to require fresh presentation. It may be further remarked that they account for scarcely any of the features which are most characteristic of eskers, and they are inconsistent with some known facts. Since explanations depending on the effects of glacial rivers are free from these objections, there is every reason why we should restrict our attention to them.

The first to propose, or rather to adumbrate, a glacier theory of eskers was Mr. N. H. Winchell.† His words are as follow:—“The effect of such a persistent obstruction [*i.e.* of a ridge of Niagara Limestone] beneath the glacier must have been to fracture the ice profoundly, those parts toward the east and toward the west settling gently away from the uplifted centre. Into these crevasses the drift would fall, and through them streams of water would flow. The result would be an extraordinary accumulation of coarse and assorted drift materials, which, after the complete withdrawal of the ice, would lie in irregular knolls and short ridges in places where such streams formerly existed. This is the origin of a great many short, but steep and narrow, gravel ridges in the North-western States outside Ohio, which are known locally as ‘Devils’ Backs,’ or ‘Hogs’ Backs.’” . . . “They generally rise from 25 to 40 feet, with slopes as steep as such material can be piled into. On either side there is usually a low, swampy tract, from three to ten rods wide, or sometimes of indefinite width and form, the ridge being in some cases not more than 20 feet across on the summit. The largest boulders are sometimes seen on the very top of the ridge.”

It is unfortunate that Professor Winchell does not identify these gravel ridges with eskers, kames, or *asar*; the more so, as some pages further on (p. 181), he thence to Meadhraighe, a peninsula extending into the Bay of Galway.” See also the (earlier) *Annals of Clonmacnois*, under Conn of the Hundred Battles, whose kingdom stretched southwards to the Esker Riada. The “phonic reasons” are certainly worth considering; every English-speaking geologist knows how to pronounce the word *esker*, but few seem to be aware of the correct pronunciation of *asar*; it is not quite “*osar*” as seems to be generally supposed. The grammatical form is a still more serious objection to the use of the Scandinavian term, for we do not readily form our plurals in *ar*.

\* *Marginal Kames*.—Proc. Acad. Nat. Sci., Philadelphia, 1885, p. 157.

† *The Surface Geology of North-Western Ohio*. By N. H. Winchell.—Proc. Amer. Assoc. Adv. Sci., vol. xxi., 1872 (1873), p. 165.

definitely mentions "ozars," only to explain them as due to "the constant breaking of the waves."

The same omission to connect the Ohio ridges with eskers occurs in later writings by this author.\* At the same time there can be no manner of doubt that the features which Professor Winchell had under observation are true eskers, and therefore we must justly assign to him a share of the credit of first attributing to them a glacial origin.

In the same year Mr. James Shaw† described gravel hills in Illinois (which appear to be eskers, though this is not expressly stated), and attributed them to the combined action of glaciers and water.

Dr. D. Hummel‡ was the first to propose and elaborate a complete and consistent theory of eskers. An excellent summary of this is given in Professor J. Geikie's *Ice Age*.§ The following account is taken from Dr. Hummel's memoir. The eskers on which the author bases his theory are those of Southern Sweden, and particularly those of the high ground, more than 400 feet above the sea-level, and so beyond the limits of the glacial submergence; in their case, consequently, an appeal to the action of the sea is excluded. The only other theory (with which the name of Törnebohm is most closely associated) making any pretence to explanation presupposes the existence of great plains of mud, through which rivers cut their way, forming valleys in which the gravel and sand of the eskers were deposited. By the subsequent removal of the mud, the eskers acquired their existing shape. Hummel remarks of this, that it is inconceivable that so much mud should have existed without leaving some trace behind; particularly as the form of the surface of the Swedish plateau is such as would be likely to prevent its complete removal. Traces of the mud-plain might certainly be expected to occur between the esker deposits and the underlying boulder-clay; but though the contact of the two latter can be plainly seen, there are no signs of the mud—on the contrary, the boulder-clay and the esker material pass into each other.

Stratified deposits covering the eskers are of rare occurrence and of inconsiderable extent: in tracts where they generally occur, one is accustomed to distinguish an interior part, or kernel, from an outer part or shell; the kernel is evidently contemporaneous with the ancient ice-sheet. This is shown by the intimate association of the Yoldia clay with the shell of the esker in the lowlands, and the occurrence of boulder-clay immediately below the kernel.

\* *The Geological and Nat. Hist. Survey of Minnesota*.—First Annual Report for the year 1872 (1873), p. 62; and Second Annual Report, 1873 (1874), p. 194.

† *Geological Survey of Illinois*, vol. v., p. 108, 1873.

‡ *Om Rullstensbildningar*, by D. Hummel.—Bihang till K. Svenska Vet. Akad. Handlingar, Bd. II., No. 11, p. 3, 1874.

§ *The Great Ice Age*, 3rd edition, 1894, p. 172.

The connection of the eskers with the inland ice is, according to this author, more definitely shown by the following :—

1. The generally close correspondence between the direction of eskers and that of glacial striation. Both are related to the direction of the flow of the inland ice, and thus to the general slope of the land and its great valley systems. At the same time they may be independent of minor, but still considerable, inequalities of the ground.

2. The not uncommon transition, which may be traced between esker material and boulder clay, within the same system of eskers, or even within a single esker; in the latter case usually towards its highest-lying end.

3. The occurrence of great perfectly angular blocks of stone on, or within, the esker; or even of a superficial covering, not unlike terminal morainic material.

4. The occurrence of marked dislocations within the esker.

While these characters indicate a connection with the ice, there are others pointing no less clearly to the influence of running water; but not of the sea, as is shown by :—

1. The absence of marine shells from the kernel of the esker, which is sometimes beautifully stratified.

2. The common occurrence of false bedding, which rarely appears in the evidently marine deposits.

3. The rarity of stratified sheets overlying the kernel of the esker.

The notion that eskers might be of marine origin was suggested by their form, which appears to require the agency of some force acting at right angles to the direction of their length.

What is required is—

1. Running water acting with considerable force, and for a sufficiently long time.

2. A force acting at right angles to the direction of the esker.

Nothing but a melting ice-sheet can give us this.

The author then turns to Greenland, and cites Nordenskiöld to show that deep crevasses occur in the ice, and that considerable streams of water flow beneath it; and that its surface is undulating. The crevasses arise in consequence of the movement of the ice, and are greatest where the movement is most rapid; they run at right angles to the direction of movement; they are deepest in the middle of a flow, and diminish towards the sides.

As regards the bottom of an ice-flow, we know that tunnels exist there, produced by the action of air and water; and these may be quite general beneath

the inland ice. If we think of an ice-sheet melting away, we must picture the water, continuously produced on its surface, finding its way down to the bottom through crevasses, producing there tunnels, the size, form, and distribution of which will depend on the movement of the water; and this, in its turn, depends on the slope of the upper surface of the ice, its crevasses, and the slope of the underlying ground. Let a valley exist on the upper surface of the ice, then we might expect to find the tunnel below the ice taking the same direction as this valley; further, let a correspondence exist between the direction of the valley on the ice, and of a valley on the underlying ground. Then, from the sides of the ice valley, and at right angles to it, the water, streaming down, will proceed, maintaining its directions through the ice; the streams of water will meet somewhere in the mountain valley below the ice, and produce a powerful effect on its lower surface. Something similar might occur, independently of the relief of the ground, if the crevasses increased in depth towards the middle of the ice-flow, and diminished towards its sides.

Such streams of water must naturally occur and precipitate themselves in numberless places along the whole length of the ice valley; streams of water, also, coming from opposite sides, will meet along a line, more or less crooked, under the ice, and thus will arise a long extended vault, or row of vaults, in the bottom of the ice, running in the same direction as the ice valley.

Given the possibility of such action of the water on the bottom of the inland ice, and the explanation of the highland eskers becomes comparatively simple. The ground-moraine is exposed to the action of the flowing water; it becomes converted by degrees into a water-worn material, which is transported by the moving water to the glacier tunnel, and is forcibly pressed in, until the tunnel is filled with it; the lateral streams are compelled, then, to form a new tunnel by the side of the old; the new one is, in turn, filled up, and another excavated, and so on. The ice thus acts both by determining the movement of the water, and by affording a mould within which water-worn material is collected. The greater the thickness of the ice, and the greater the fall of water, the larger the sub-glacial tunnels, and the greater the dimensions of the eskers. On quite level tracts of boulder-clay the eskers attain no great height, but still present a plainly recognisable form, and are often bordered by peat-filled depressions at the sides.

These lateral depressions—esker moats—are very characteristic features; while in some places inconspicuous, in others they attain a considerable size, and not seldom form a large basin from which several eskers of well-defined form proceed. When not due to the form of the glacial tunnels, they may result from the excavating action of water, which, pouring down the sides of the ice, scours out the moat, and afterwards builds up the excavated material into the esker. Thus the moat might be the first stage in the formation of the esker.

The kettle-holes, which occur between two closely adjacent eskers, are probably due to the form of the bottom surface of the ice; those, however, which run down the middle of a single ridge are possibly a consequence of waterfalls through the ice. The interruptions of the eskers, their variation in height, and winding form, even within a well-marked valley, are all the natural result of changes in the number and strength of the lateral rivers. That the windings have been so well preserved may be due to the cessation of the movement of the ice, shortly after their formation, as a consequence of its melting.

The frequent deviation of eskers from the direction of the glacial striation is due to the ramifications of the ice valleys; and from these ramifications also result esker spurs and knots.

The absence of eskers from large wide valleys might be explained, in cases where the ice was not moving with the slope of the ground, by assuming that the watershed of the drainage on the ice ran along with, or across, the hollow of the underlying valley.

It is to be remarked that:—

1. Eskers usually proceed through valleys, even when these occur on plateaus.
2. The slope of the inland ice, if its thickness be comparatively small, is dependent on the slope of the ground, and the more so as melting proceeds.
3. Valleys in the land, particularly in high-lying tracts, exert an important influence on the position, or direction, of the ice-flow, or its depressions; the more especially as the whole movement of the ice in the latest times followed, in general, the large and regular valleys.

That exceptions to the above rules are numerous appears from a comparison of the direction of eskers and glacial striæ; and their significance is great, as by them, alone, can we obtain simple explanations of such facts as the following:—

The often obvious independence of the eskers and the slope of the ground, their great and numerous interruptions, their isolated position, the appearance they often present of having been very rapidly heaped together. These facts may be regarded as the effects of changes in, and on, the inland ice, and in the volume and velocity of the lateral streams.

That the ice and the subglacial rivers may have moved in contrary directions, for longer or shorter distances, is clearly shown by observations on the structure of some gravel deposits; the most beautiful example occurs between Hilleshult and Svensbygget (Halland). At the S.W. end, on the highest ground, this is extremely insignificant, and consists only of pebbles; its dimensions increase rapidly towards the N.E., but the material does not change until near Hilleshult; there the pebbles are fewer, the material is more water-worn, and there is more sand. This change of structure, on the whole, obtains less, if at all, in the definite

esker which winds along through the same great area of gravel. Since the water-worn material diminishes from S.W. to N.E., it is clear that the water flowed in this direction, while the glacial striæ show that the movement of the ice was from N.E. to S.W. The existing river now flows in the same direction as that which carried the gravel.

Hummel's famous Paper was followed by one equally well-known by Dr. Holst.\* A short account (by Dr. Lindahl) of this Paper was published in the *American Naturalist*, vol. xxii, 1888, pp. 589 and 705. The author commences with a powerful criticism on the marine and mud-plain theories, which he has little difficulty in demolishing. He rightly points out that the mud-plain theory had, at least, the merit of perceiving that the esker required sustaining walls for its formation, and that these have since disappeared, and that it recognised the resemblance of an esker to a river deposit. [One may remark that the same material, viz. mud, was at one time invoked to do other duty, which has since been assigned to ice, such as transporting erratics and polishing and striating rock surfaces.] Holst fully recognises the merit of Hummel's theory so far as it depends on the presence of the inland ice, but he thinks it less fortunate in its details, particularly in assigning the origin of the eskers to tunnels below the ice. The formation of the subglacial tunnels, as described by Hummel, affords a fair opportunity for a damaging attack; but since the observations of Russel on the Malaspina Glacier, the whole treatment of this part of the subject, both by Holst and Hummel, appears speculative and artificial.

Dr. Holst then proceeds to explain his own views. On the melting of the inland ice, streams form upon its surface, which work back from the margin of the ice until they form ice-cañons; at the same time englacial drift (which is assumed to exist in considerable quantity) is set free, worn by running water into rounded gravel, and sorted and arranged in layers on the bed of the stream. Thus the englacial fragments, which lay near the upper surface of the ice, form the lower layers of the esker.

On the final melting of the ice the deposits in the river-bed remain behind as an esker. Nordenskiöld's description of a broad and deep river flowing on the surface of the Greenland ice is appealed to; and it is pointed out that the size of this river points to its having flowed for some distance before arriving at the place where it was observed. This river, a little lower down, certainly precipitates itself through the ice and disappears; but since crevasses depend on the movement of the ice, when the ice was melting away and becoming stationary, they would diminish and might almost disappear. Or if crevasses occur in the ice, they must be in union with one another and with the free margin of the ice;

\* *Om de glaciala rullstensåsarne*, by N. O. Holst, Geol. Forens. i Stockholm Förhandlingar, Bd. III. p. 97, 1876 and 1877.

otherwise the water, which finds its way down in the higher regions to the bottom of the ice, will rise again to the surface at lower levels, and find its way over it.

The surface of eskers is sometimes covered with angular detritus; this is englacial drift, which was deposited in the last stages of the melting of the ice, when the running water was diminishing in strength.

Serious reasons are given for doubting the possibility of the formation of eskers from bottom moraine, at least in the manner supposed by Hummel.

As regards the kettle-holes of eskers, Nordenskiöld and Levin have suggested that water, streaming through the loose material of the esker, has carried away the fine sand, and so caused a settling of the residual material; thus forming a kettle-hole. This is very improbable. If such a process really occurred, we should expect to find at the bottom of a kettle-hole more large stones and coarser gravel than in other parts of the esker; but this is not the case. Kettle-holes are original, not super-induced, features of an esker. They may be explained as marking the position of islands of ice which stood up in the middle of the rivers of the ice-sheet.

A somewhat similar explanation will apply to the interruptions which so frequently occur in the course of an esker. A rapid accumulation of pebbles, for instance, may cause a diversion in the course of the river, so that instead of flowing through a cañon, it will proceed over or under the ice.

The author gives the following summary of his conclusions:—

1. Eskers were formed in running water.
2. No running water has the power to lift the contents of an esker to the considerable heights at which they so often occur.
3. The material must, therefore, have been lifted up by the ice, and from it carried down and heaped together in the eskers, somewhat after the fashion described above.

In the discussion following the reading of Dr. Holst's Paper, Nordenskiöld, Torell, and Törnebohm, took part; and it was pointed out that neither Hummel's nor Holst's theories accounted for all the peculiar features of an esker. Nordenskiöld called attention to the manner in which the great sand plains of North Asia are being denuded, as suggesting a possible explanation of the mode of formation of some eskers.

The first geologist in America to propound a general glacial theory of eskers was Warren Upham,\* whose work has all the interest of independent discovery; for Winchell's explanation of a particular case, in no sense a general theory, was

\* *On the Origin of Kames or Eskers*, by Warren Upham.—Proc. Amer. Assoc. Adv. Sci., 1876 (1877), p. 216.

obviously and naturally unknown to him. He was also unaware of the work of Hummel and Holst, this being then very recent, and moreover published in the Swedish language. Great credit further is due to Upham, owing to the fact that the phenomena are not so simple in New Hampshire as elsewhere, the eskers in that State being buried to a great extent beneath plains of alluvial deposit. I give this author's theory in his own words:—"Through the whole glacial period rivers probably existed, to some extent, beneath the ice; but their volume and strength . . . greatly increased during the final melting of the ice-sheet. In many instances these probably filled deep channels along lines of depression upon the surface of the glacier, which, at the last part of the melting, would coincide nearly with our present valleys; or oftener, probably, they formed for themselves great tunnels beneath the ice, seeking, of course, the lowest land for their route. By these glacial rivers, which flowed beneath, or on, the ice, discharging the water supplied by its melting, there were deposited, from the low water of winter, layers of sand, and from the strong currents of summer layers of gravel, often very coarse, which would be very irregularly bedded, here sand and there gravel accumulating, and, without much order, interstratified with each other. At the melting of the ice-walls on each side of these glacial rivers, the materials, which had collected to a great depth in their channels, were left in long ridges, a section of which would show an irregular anticlinal stratification. . . . Mounds or irregular short ridges . . . have probably resulted from the rapid deposition of these rivers as the last of the glacier was melting away, ridges and irregular masses of ice having existed where there are now hollows or ponds. These irregular accumulations of sand and gravel were many years ago attributed to similar causes by Dr. Edward Hitchcock, who accordingly named them moraine terraces. The occurrence of occasional angular boulders enclosed within, or lying on, the surface of kames is readily explained, as the course of the rivers was probably in most cases beneath the glacier, and they would be dropped from the melting of the ice overhead. From explorations in the Alps and Greenland we know that streams in summer are found flowing on the surface of glaciers, and that falling through crevasses these gather to form considerable rivers beneath the ice."

In the year 1877, the second edition of "The Great Ice Age," by Professor James Geikie, was published. It contains a notice of Holst's views, and an account of Hummel's theory, which the author, abandoning the marine theory, accepts.

Warren Upham\* published a full and complete account of the eskers of New Hampshire in the following year. In this he considerably modifies the views he had at first expressed, so that they now more closely resemble those of Holst than

\* *The Geology of New Hampshire*, 1878.

of Hummel. Thus, while admitting that in some cases eskers may have been formed by sub-glacial streams, he considers that, in general, the streams were super-glacial. He thinks that the deposition of the eskers took place chiefly at the mouths of these rivers, and extended along the valleys as fast as the ice-front retreated; and finally he no longer regards the large angular erratics, occasionally associated with eskers, as having been left behind by a melting glacier, but as dropped from floating ice.

In the same year Professor Newberry\* describes the kames of Ohio as differing in some respects from typical eskers. "They occupy a topographical position which makes it impossible that they should have been the beds of rivers; for they form a belt along the summit of the divide between the lake-basin and the Ohio valley, all the way across the State"; and he concludes that they "have been formed by the action of water on the morainic material of the Erie clay"; but "how the necessary floods could be produced, there, is a difficult problem."

A valuable contribution to the study of eskers was published by Professor G. H. Stone in 1881.† Briefly summarised, Mr. Stone's results are as follows:—The eskers of Maine are found at all elevations above the sea up to a height of about 1600 feet. They freely cross transverse hills 100 feet in height, even when a little deflection would give them a course through a valley. None surmount hills of over 200 feet. No instance is known where a kame, after entering a valley bordered by hills more than 200 feet high, has left it, however crooked the valley may be. The only surface features which seem to invariably determine the location of eskers are drainage basins and hills more than about 200 feet high, measured on the north. In many instances eskers cross the beds of lakes, sometimes for many miles, and can be traced under water.

The observations of the author on the transport of the material of the eskers are so important that I give the following extract in full:—"With the exception of one short outcrop of granite the course of system ix. lies wholly within a region of slates, conglomerates, and limestones, for nearly 100 miles. It then crosses the granitic range of mountains extending north-eastward from Mount Desert. For seven miles after entering the granite area in Aurora the kame is composed almost wholly of slate, although the country on both sides is covered by granitic till, and shows multitudes of granite boulders and fragments. The granite then begins to appear in the kame, and, a few miles farther south-eastward, the kame plains are almost wholly composed of granite, although the underlying rock is there a micaceous slate or schist, and the till shows that kind of rock freely. These and other facts of similar import show that the kame materials have been

\* *Rep. Geol. Surv. Ohio*, vol. iii., p. 40, 1878.

† *The Kames or Eskers of Maine*, by George H. Stone.—*Proc. Amer. Assoc. Adv. Sci.*, 1880 (1881), p. 510; and *On the Kames of Maine*.—*Proc. Boston Soc. Nat. Hist.*, 1880 (1881), p. 430.

transported lengthwise of the kames, and in general farther than morainal material originally derived from the same locality. In other words, kame drift is glacial drift plus a variable amount of water drift." The proof which the foregoing extract affords of the transport of material composing the esker, in a direction corresponding to its length and to its downward slope to the south, is confirmed by the observation that the gravel is less rounded and waterworn in the eskers near their origin on the north than farther south, and further by the prevailing direction of the dip of the stratification of the esker material, as well as by the expansion of many of the eskers into broad kame plains, as they approach their southern termination.

In their meandering, branching, looping, and other characters, the eskers of Maine precisely resemble those of this country; but they are of much greater length, sometimes extending for a distance of 150 miles.

The following extract will complete our account of this admirable memoir:—"During the Champlain Period, the sea probably stood in the central parts of Maine at a height of 300 or 400 feet above its present level, and many kames were submerged during that period. The sides of a kame that has not been under the sea usually slope at the angle of stability of loose materials in air; while those that have been submerged have the form of low rounded bars, whose sides slope at the angle of stability of such materials in water. The fossiliferous Champlain Clays have hundreds of times been seen overlying the kames, and I have taken *Mya*, *Balanus*, and shells of other marine genera from the undisturbed clay found in the depression in a kame. The difference, in the physiognomy and structure of the kame which has been under the sea and that which has not, is so great as to show conclusively that the kames proper cannot have been of marine origin."—(Proc. Amer. Soc. Adv. Sci., *loc. cit.*, p. 518).

"Again, the kames bear the same relation to drainage basins as ordinary streams. At their northern ends, all, so far as known, originate in places favourable for collecting a considerable body of water from the melting glacier. That the flow of water was swifter in some parts of the streams than in others is shown by the nature of the deposits. Short slopes do not seem to have much affected the rate of flow, but on up-slopes or levels of several miles in length, the kames are usually large and of fine material, while on long down-slopes, or near the height of the higher divides, or in the jaws of narrow passes, they may wholly disappear, or be represented by the larger pebbles only. Every long kame-system in the State shows this alternation of finer and coarser material varying according to the slope. The map shows how often the kames disregard the lines of natural drainage. From this it may be inferred that these rivers were contained within ice walls, and that the ice surface was far from agreeing with the underlying land surface. That these rivers, for the most part, flowed in superficial channels in the ice is a fair

inference from the facts observed. Thus far but few signs of sub-glacial streams have been recognised far back from the coast. Near the coast there are some evident signs of such streams, and some kames may have been deposited by them.” —(*Ibid.*, p. 516).

A study of the eskers of Connecticut Valley by Professor Dana\* led him to doubt whether they were genuine eskers, and to contend that they are merely coarser parts of a system of alluvial terraces.

A theory, which has at least the merit of novelty, was proposed by Professor Shaler in 1884.† It will be readily understood from the following short citation:—“This association of kames with drift deposits formed beneath the surface of water, long ago led me to the hypothesis that the ordinary kames are structures that were made beneath the surface of water-covered regions, and that they accumulated at the points where subglacial rivers discharged their streams beneath the ice into the sea, or the temporary lakes that abounded over the land-surface during the glacial period.” Subsequent investigation has, however, led him to relinquish this explanation.

An interesting Paper was read before the British Association in 1884 by Professor Carvill Lewis.‡ It contains a general account of eskers, of the literature of the subject, and of proposed explanations. The author agrees that either they “must have been enclosed within high walls of ice, or the streams of water which formed them must have flowed in subglacial tunnels.” The direct object of the paper is the description of certain eskers in Pennsylvania, which stand in close connection with the great terminal moraine, being sometimes continuous with it; they are all short, from a few hundred feet to a few miles in length, and they slope downwards towards a river valley, or other watercourse, in the opposite direction to the movement of the once overlying ice. Professor Lewis consequently concludes that they were formed by a backward sub-glacial drainage.

Professor Winchell,§ after describing an important esker, which he names the Bridgewater kame, gives a long series of important conclusions which he thinks may be drawn from it. Briefly summarised, these are that the esker was formed by an existing river, “Straight River,” at a time when its waters flowed over the upper surface of a glacier.

Kames are described as occurring in Canada by Mr. R. W. Ells and Mr. R. Chalmers.|| Both of these observers call attention to the resemblance in the course

\* *The Kames of Connecticut Valley*, by J. D. Dana.—*Amer. Journ. Sci.*, vol. xxii., 1881 (1882).

† *On the Origin of Kames*, by N. S. Shaler.—*Proc. Boston Soc. Nat. Hist.*, vol. xxiii., p. 36, 1884.

‡ *On Marginal Kames*, by H. Carvill Lewis.—*Proc. Acad. Nat. Sci. Philadelphia*, 1885, p. 157.

§ *The Geology of Minnesota*.—*Final Report*, vol. i., 1884, p. 665.

|| *Geol. Survey of Canada*, 1885, p. 65 E. and 28 GG.

of the eskers to a winding river; the esker described by Mr. Ells runs along with the Hebert River, which is considered to have had some share in its formation. Mr. Chalmers attributes the kames observed by him to post-glacial streams.

There is a short reference to eskers by Professor Shaler in 1889\*; it is chiefly interesting for its virtual retractation of his earlier views, and the statement that he regards eskers as formed within sub-glacial channels during the last stages of the melting of the ice-sheet.

Numerous eskers and kames are described by Mr. Warren Upham in different parts of Minnesota,† and referred to the action of streams flowing through cañons in the ice.

A very welcome addition was made to our knowledge in 1890 by Professor G. F. Wright in his work on *The Ice Age in North America* (Kegan Paul & Co., London), containing (p. 62) a description of eskers actually in process of formation. It runs as follows:—

“Now that the front is retreating, this sub-glacial stream occupies a long tunnel, twenty-five or thirty feet high, in a stratum of ice which is overlaid to a depth, in some places, of fifteen or twenty feet with waterworn glacial *débris*. In numerous places the roof of this tunnel has broken in, so that the overlying *débris* is caving down into it. In places the tunnel is deserted by the stream, and the accumulating *débris* thus forms a tortuous ridge, with projecting knolls where the tunnels are oldest and largest. At the same time the ice on the sides at some distance from the tunnel, where the superficial *débris* was thinner, has melted down much below the level of that which was protected by the thicker deposit; and so the *débris* is sliding down the sides as well as into the tunnel through the centre. Thus three ridges, approximately parallel, are simultaneously forming, one in the middle of the tunnel, and one on each side. When the ice has fully melted away, this *débris* will present all the complication of interlacing ridges, with numerous kettle-holes and knobs characterising the kames; and these will be approximately parallel with the line of glacial motion.” Again (p. 300):—“Of course these glacial streams must, in the main, have followed the great valleys; but many of the minor valleys were, at that time, so obstructed that the streams might disregard them and take a more direct route over the ice through the open channels and long tunnels which must have existed. Those familiar only with the contracted glaciers of the Alps are scarcely prepared to appreciate the extent to which currents of water flow over the larger glacial masses and rearrange and transport the superficial material collected on them. The ‘sub-glacial’ streams also are not always strictly sub-glacial; since they often flow through tunnels which are midway between the top and the bottom of the ice-mass. In the Muir

\* Ninth Annual Report Geol. Survey, United States, 1887, 1888, 1889, p. 550.

† *Geology of Minnesota*, Final Report, vol. ii., 1888.

glacier, Alaska, for example, the two streams issuing from the ice-front near the sides of the glacier are several hundred feet above the level at which the two streams emerge near the centre of the channel. There, also, streams of water of more or less size, can occasionally be seen pouring out from the perpendicular front of the ice a hundred feet or more above the surface of the inlet. Nor is it any uncommon thing to see icebergs move off with water-worn tunnels in them which are still well filled with gravel and pebbles. In the various depressions in the surface of the glacier also, where, at times, extensive lakes of water are formed, there is much accumulation and assortment of earthy material far back from the terminal margin of the glacier."

Another important contribution to our knowledge of melting glaciers is furnished by Mr. Russell in his account of the Malaspina glacier of Alaska.\* This glacier the author regards as the type of a hitherto not fully recognised class, which he terms "*piedmont* glaciers," because they form at the foot of mountains, by the union and expansion of tributary mountain glaciers. The Malaspina glacier extends continuously from Yakutat Bay for seventy miles westward, and has an average breadth of twenty-five miles. It is a vast, nearly horizontal plateau of ice, having, at a distance of five or six miles from its outer border, an elevation of about 1500 feet. After giving an account of the drainage of the glacier, the author adds:—

"The drainage of the Malaspina glacier has not been investigated as fully as its importance demands; but the observations already made seem to warrant certain conclusions in reference to deposits made within the glacier by subglacial or englacial streams. When the streams from the north reach the Malaspina glacier they invariably flow in tunnels and disappear from view. The entrances to these tunnels are frequently high arches, and the streams flowing into them carry along great quantities of gravel and sand. . . . About the southern and eastern borders of the glacier, where the streams emerge, the arches of the tunnels are low, owing to the accumulation of *débris* which obstructs their discharge. In some instances, as at the head of Fountain stream, the accumulation of *débris* is so great that the water rises through a vertical shaft in order to reach the surface, and rushes upwards under great pressure. . . . The streams flowing from the glacier bring out large quantities of well-rounded sand and gravel, much of which is immediately deposited in alluvial cones. This much of the work of subglacial streams is open to view, and enables one to infer as to what takes place within the tunnels.

"The streams issuing from the ice are ever loaded with detritus, and, besides, on emerging, frequently receive large quantities of coarse *débris* from the adjacent

\* *Second Expedition to Mount St. Elias in 1891*, by I. C. Russell.—13th Ann. Rep. U. S. Geol. Survey, 1893; and on *The Malaspina Glacier*, *The Journal of Geology*, vol. i., 1893, p. 219.

moraine-covered ice-cliffs. The streams at once deposit the coarser portion of this, thus building up their channels and obstructing the outlets of the tunnels. The blocking up of the tunnels must cause the subglacial streams to lose force, and deposit sand and gravel on the bottom of the channels; this causes the water to flow at higher levels, and coming in contact with the roofs of the tunnels, enlarges them upwards; this, in turn, gives room for additional deposits within the ice, as the alluvial cones at the extremities of the tunnels grow in height. In this way narrow ridges of gravel and sand, having perhaps some stratification due to periodic changes in the volume of the streams, owing to seasonal changes, may be formed within the ice. When the glacier melts, the gravel ridge contained within it will be exposed at the surface, and as the supporting walls melt away, the gravel at the top of the ridge will tend to slide down, so as to give to the deposit a pseudo-anticlinal structure. Ridges of gravel deposited in tunnels beneath the moraine-covered portion of the Malaspina glacier would have boulders dropped upon them as the ice melts; but where the glacier is free from surface *débris* there would be no angular material left upon the ridges when the ice finally disappeared."

Such is the author's explanation of the formation of eskers. He adds:—"The process of subglacial deposition pertains especially to stagnant glaciers of the Malaspina type, which are wasting away. In an advancing glacier it is evident that the conditions would be different, and subglacial erosion might take the place of subglacial deposition."

Warren Upham briefly recurs to the subject of eskers in discussing the "*Criteria of Englacial and Subglacial Drift*,"\* and maintains his previously expressed views in favour of the deposition of eskers within ice-cañons.

In an interesting account of the sand-plains, eskers, and kames of the Auburn-dale district, ten miles east of Boston, Mr. W. M. Davis† shows how these different features are genetically connected, and attributes the eskers to subglacial streams, without denying that in other districts they may have a superglacial origin.

Mr. Warren Upham‡ supports the view that much of the glacial drift was carried within the substance of the ice, and cites Bird's Hill esker, near Winnipeg, as proving that englacial drift had been carried up from a nearly level country to a height of more than 500 feet in the ice-sheet.

Professor Salisbury§ describes eskers which have been mapped by Professor Culver. They are ascribed to streams flowing from the ice-sheet.

\* *The American Geologist*, vol. viii., 1891, p. 380.

† *The Subglacial Origin of Certain Eskers*, by W. M. Davis.—*Proc. Boston Soc. Nat. Hist.*, vol. xxv., p. 477, 1890–1892.

‡ *On Englacial Drift*, by Warren Upham: *The American Geologist*, vol. xii., p. 36, 1893.

§ *Ann. Report Geol. Survey, N. J., Trenton*, 1893.

Mr. W. O. Crosby\* writes of eskers as formed by sub- and super-glacial streams ; but subsequently speaks of superglacial rivers alone. Thus he says:—"The glacial streams had undoubtedly, in many cases, deeply grooved and divided the marginal portion of the ice, and in these grooves or channels was accumulated, after the manner of rivers, the narrow deposits of sand and gravel, which, when the ice melted away, became the steep winding ridges which we call kames and eskers. At the mouths of these glacial rivers, delta-plains were formed in the lakes, adjacent deltas often becoming confluent. The plains are thus naturally coincident in height with the eskers and often appear as expansions of the latter."

The subglacial origin of eskers is again asserted by Mr. Stone,† in an interesting, but highly theoretical, Paper, in which he calls attention to the fact that, in the State of Maine, along 200 miles of coast, the eskers decrease in size as they proceed towards the sea ; at the same time becoming increasingly discontinuous, until they terminate near the heads of fjords, without extending beneath the sea. Mr. Stone thinks an explanation may be found in the glacial submergence, which prevented the subglacial tunnels in that part of the ice which entered the sea from enlarging with the same rapidity that they did elsewhere ; the result being that the subglacial rivers, being confined within narrower channels, flowed with such velocity that detritus was swept away and deposition rendered impossible.‡

Mr. Stone's Paper is followed by a very important contribution from Professor Chamberlin,§ who shows that drumlins are essentially of subglacial origin, and that kames are associated with them in such a manner as to prove that the gravel of the kames "is but a partially assorted derivative from the till of the region." A somewhat similar result is reached in the case of eskers.

A very instructive model showing the relations of sand-plains, eskers, and kames to each other, and to the stagnant glacier which is supposed to have produced them, are described by Mr. F. P. Gulliver.||

A suggestive Paper, by Mr. J. B. Woodworth,¶ appeared in 1894. In discussing the variation of the crest-line of eskers in height above the surrounding country, the author suggests that this may be connected with changes in the breadth of the

\* *Geology of the Boston Basin*, by W. O. Crosby : Occasional Papers of the Boston Soc. Nat. Hist. IV., vol. i., pp. 160 and 274, 1893 and 1894.

† *The Osar Gravels of the Coast of Maine*, by George H. Stone : Journ. Geology, Chicago, vol. i., p. 246, 1893.

‡ A review of this Paper appeared in the *American Geologist*, vol. xii., p. 122, criticising some of its conclusions. A reply by Mr. Stone follows in the same volume, p. 200.

§ *The Horizon of Drumlin, Osar and Kame Formation*, by T. C. Chamberlin : Journ. Geology, Chicago, vol. i., p. 255, 1893.

|| Journ. Geology, Chicago, vol. i., p. 803, 1893.

¶ *Some Typical Eskers of Southern New England*, by J. B. Woodworth.—Proc. Boston Soc. Nat. Hist., vol. xxvi., 1894, p. 197.

ridge. For suppose the esker to have had originally a rectangular section, and to have acquired its existing form by the sliding down of materials, along its sides, then if the base of the rectangle is greater than the altitude, in any ratio greater than 3 to 2, the final height of the esker, after sliding, will be the same as the original height; but if the ratio be less than this, the final height will be less than the original height; thus in one and the same esker-ridge we should expect to find the broader portions higher than the narrower.

An attempt is then made to show that the variation in height is connected with changes in direction of the esker, and with associated changes in the width of the meandering ice channel in which it was formed. The author admits, however, that "many eskers do not display a consistent and regular variation in their lines."

In the abstract of my Paper,\* on *A map of the Esker Systems of Ireland*, it is said that the esker may represent a "cast," as it were, of a glacier-tunnel in gravel and sand. On this hypothesis, all the known characters of eskers find an explanation, as well as many incidental details, such as the long lakelets, or shallow streams, by which they are not infrequently flanked. The details of the explanation are not given; but this defect is supplied by Mr. Woodworth, who, to my great satisfaction, has arrived at a view precisely similar to my own. I reproduce the diagram which

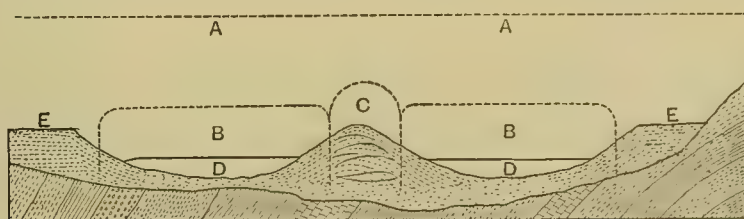


FIG. 1. (From Mr. Woodworth's Paper just referred to.)

Generalized section across meridional valley, with lateral moraine terraces (or hillside kames), with medial esker, showing symmetry due to deposition of sands and gravels in the presence of melting valley-tongues of the ice-sheet. AA, ice-sheet previous to the stage BB, when isolated blocks hold open cavities between the esker and the terraces, EE. C is the tunnel in AA in which the esker originates. DD, esker ponds or swamps.

he gives in illustration of this view. Dr. Hummel's explanation of the esker-moat has been given previously (*v. antea*, p. 791). On reviewing the preceding account—which is far from complete—it will be seen that ever since Hummel first attributed the peculiar features of eskers to the influence of once existing ice, geologists, familiar with these features, have, with almost one accord, expressed themselves in agreement with this explanation. Nor could it well have been otherwise. Some material must have existed to furnish a support to the sides of the eskers, during their formation; but this material has since completely disappeared; and the only substance at all likely to have behaved in this manner is ice.

\* Rep. Brit. Ass. Adv. Sci., p. 777, 1893.

When from this general statement, we pass to matters of detail, unanimity is at an end, and geologists are found occupying two opposing camps, one represented by Hummel and the other by Holst, with intermediaries who agree with both. The one regards ground-moraine as the source of the material of the esker, the other prefers to derive it from superglacial or englacial drift; the one pictures its deposition in subglacial tunnels, the other in ice cañons.

Much time has been spent in speculative discussion of these points—time not wholly wasted, since the imagination having produced many pictures of what might have occurred, observation has been assisted in its task of more speedily recognising, in the field, those phenomena which are serviceable for explanation. The only observations which we possess, directly bearing on the question, are those of Wright and Russell; and these agree in referring the place of deposition of eskers to tunnels in the ice, not necessarily at its base, and in attributing their material, at all events to a large extent, to superficial moraine matter. So far as observation helps us, it finds truth in the views of both Hummel and Holst; though in both, likewise, some error. The glaciers described by Wright and Russell, though dwindling, are not in the final stages of dissolution; and thus many important problems connected with the formation of eskers still wait for solution: such, in particular, as the remarkable manner in which they run up and down over hills 100 to 200 feet in height.

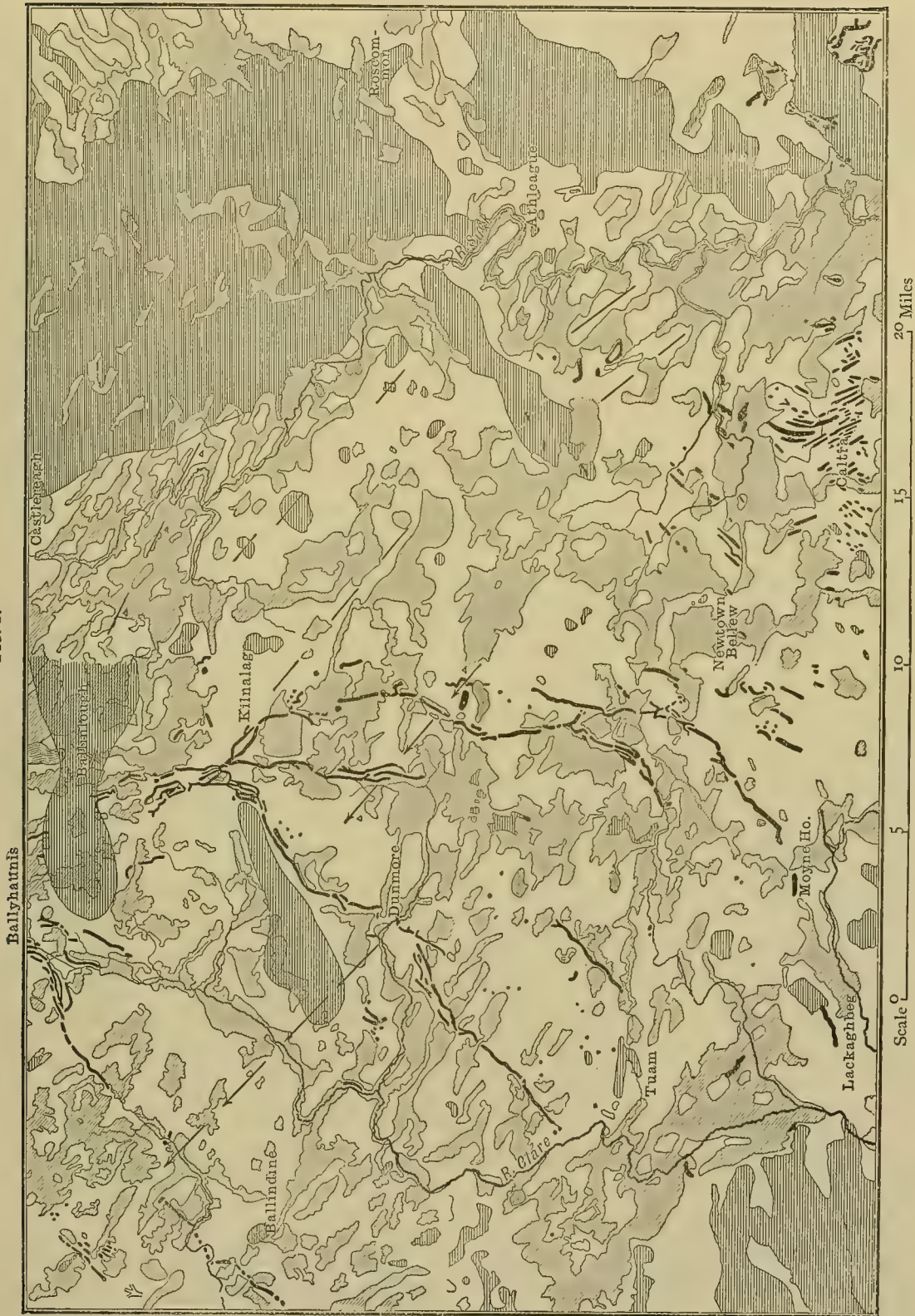
We now pass to the classification and description of the chief systems of eskers met with in Ireland. For the information on which this is based I am almost wholly indebted to the published writings of my colleagues on the Geological Survey; and the information on the map, also, which this account is intended to explain, is abstracted from the one-inch maps of the Survey.

#### *The System of Ballyhaunis.*

This system consists of five principal chains, with several outlying mounds and ridges distributed over the eastern part of county Galway, the west of county Roscommon, and the south of county Mayo. Enumerated in the order in which they are encountered, on proceeding from north and west to south and east, these chains may be named as follows:—

1. Ballindine chain, with an outlying group of ridges, north of Claremorris, in county Mayo.
2. Dunmore chain.
3. Tuam chain.
4. Kilnalag chain.
5. Moyne chain.
6. Newtown-Bellew chain. (All in fig. 2.)

Fig. 2.



These are represented on sheets numbered 76, 86, and 96 of the one-inch map of the Geological Survey, and are described in the corresponding "Memoirs," by Messrs. R. G. Symes, and S. B. Wilkinson. To the south, in southern Galway, on sheets 105 and 106, are fragmentary chains, described by Mr. G. H. Kinahan, which may possibly belong to this system. The more important are:—

7. Kilcorman chain.

9. Monivea chain.

8. Athenry chain.

10. Gortachalla chain.

Widely separated on the south and west, these chains pursue an undulating and often broken course; at first more or less parallel, trending from south-west to north-east; afterwards, turning more towards the north, or even west of north, they converge towards the small town of Kilkelly, county Mayo, 9 miles N.N.W. of Ballyhaunis; sometimes meeting and uniting on the way. Thus the Moyne and Kilnalag chains (fig. 2) unite just before reaching the hamlet of Kilnalag, forming an acute angle open towards the south; the single chain so produced joins, a little further to the north, with that of Tuam, which, in turn, becomes closely associated with the chain of Dunmore. The western slopes of these chains are frequently abrupt; those on the east are gentler. The four chains, thus united, may be termed the sub-system of Ballinlough.

1. *The Ballindine chain.*—This, the most westerly chain (fig. 2), begins between Claremorris and Ballindine, both in county Mayo; its trend is mainly from south-west to north-east; and, though much interrupted by numerous gaps, some of them over two miles in length, it is clearly traceable past Ballyhaunis, and as far as one mile beyond it. Its component eskers lie, for the most part, in a single series, but towards the north they form a multiple series by branching; the branches sometimes re-unite, enclosing elongated depressions. The three northernmost ridges pass, on the north of Ballyhaunis, into a flat-topped mound, the surface of which is 340 feet above sea-level, and 80 feet above the surrounding country on its eastern side; a single ridge is continued northwards from this mound with the same elevation above sea-level, but with a height of only 60 feet above the surrounding country. About one mile south of the mound, as shown on the map, one of the ridges of the chain attains a height of 363 feet, but it is only 43 feet above the surrounding country.

The three small eskers, seen south of Ballyhaunis (fig. 2) may be regarded as parallel outlying members of the Ballindine chain; but the cluster on the west near Claremorris, and the small group to the north near Kilkelly, cannot be brought into direct relation with this chain.

2. *The Dunmore chain.*—This fairly continuous chain (fig. 2) extends from south-west to north-east for about 14 miles before it joins the *plexus* or knot, of Ballinlough. Though a single series for the most part, it is in some places

accompanied by one or more parallel ridges, and about one mile from its confluence with the eastern chains it becomes a *plexus*, formed by the union of four approximately parallel ridges. It is difficult to estimate its height, on account of the undulating nature of the surrounding country, which is sometimes higher on one side of an esker than on the other; from 30 to 60 feet is a sufficiently close approximation. The following Table shows how the chain rises in passing from south to north, the ground rising with it:—

Miles from Origin.	Height above Sea-level (in feet).	Height of Country above do. (in feet).	Esker's own Height (in feet).
2·00	245	204	41
3·60	243	207	36
6·50	273	239	34
8·50	281	W. 217, E. 234	55 or 56
13·25	327	—	—

North of Dunmore, up to its confluence with the eastern chains, the chain lies in a broad, gentle depression; the ground on each side rising gradually to a height of between 400 or 500 feet above the sea.

3. *The Tuam chain.*—This (fig. 2) is of about the same length as the Dunmore chain, but it is interrupted in the middle by a wide gap about  $5\frac{1}{2}$  miles long. Its southern moiety runs at first from west to east, but soon turns into the south-west to north-east direction, taken by the corresponding parts of the more continuous chains; the northern moiety runs due north. The following Table shows that this chain, like the preceding, rises as it proceeds north; the country rising with it in the same direction:—

Miles from Origin.	Height above Sea-level (in feet).	Height of Country above do. (in feet).	Esker's own Height (in ft.)
1·00	297	245	52
2·25	322	286	36
4·60	338	303	35

The country between the Dunmore and Tuam chains is richly dotted over with conical gravel mounds.

4. *The Kilnalag chain.*—This chain (fig. 2), which is not quite 14 miles in length, runs at first from south-west to north-east, and then turns due north, which direction it maintains for the greater part of its course. At Ballyphilipeen,

about 3 miles from its origin, it receives a tributary which arises close to the Moyne chain on the east, and immediately south of Kilnalag, where it enters Loughapollboy bog, it is definitely joined by the Moyne chain. Past Kilnalag it becomes a double chain enclosing an elongated depression, and then unites with the Tuam chain.

The next Table shows the changes which this esker chain undergoes in elevation above the sea, and in its own height, as we proceed along it northwards:—

Miles from Origin.	Height above Sea-level (in feet).	Height of Country above do. (in feet).	Esker's own Height (in ft.)
2·00	293	260	33
2·75	312	286	26
5·00	321	276	45
8·00	333	292	41
8·50	327	296	31
11·75	350	311	39
13·00	346	298	48

5.—*The Moyne chain.*—It is difficult to determine the commencement of this chain (fig. 2) on the south. It may begin with the isolated esker near Ballynapark, or possibly with that of Lackaghbeg, 5 miles further to the south-west; a gap about 3 miles long separates the Ballynapark esker from another isolated ridge, running from west to east, on which Moyne House stands; and another gap of about one mile intervenes between this and the main part of the chain, which runs for the next 8 miles of its course almost continuously; and though it retains at first, and for a short distance, the west to east direction of the more broken ridges, it soon turns towards the north-east, and finally due north. For the last 7 miles of its course the chain is very much interrupted, the gaps being much longer than the ridges. On reference to the map it will be seen that the height of this chain, also, above sea-level, increases as we follow it from south to north. (*Mem.*—In fig. 2, “Lackaghbeg” should be “Ballynapark.” Lackaghbeg lies a little outside the southern boundary of this map.)

6. *The Newtown-Bellew chain.*—Where the Moyne chain bends round from a north-eastward to a due northward direction, it receives a tributary (fig. 2) which may have been fed by the same streams that deposited three parallel eskers, which lie not far from it on the S.E., and which trend from S.S.W. to N.N.E.

Still further to the south many scattered eskers occur, some of which may be brought into connection with these just mentioned. They are difficult to classify, but may be tentatively arranged as follows:—

7. *The Kilcornan chain.*—Near the mouth of the Clarin river, which opens into Galway bay, is a single chain of eskers which runs towards the north-east up the Clarin valley, past Kilcornan, towards Greethill. This may possibly have belonged to the same system of drainage as that of the chains already described, further to the north; but in the absence of evidence it is impossible to speak more definitely.

8. *The Athenry chain.*—This consists of two branches, the Greethill and the Loughan chains, which unite about one mile north-east of Athenry. The Loughan chain is a complicated group of parallel ridges receiving short tributaries.

9. *The Monivea chain.*—West and north of Athenry a much interrupted and multiple chain runs from the south-west towards Menlough, on the north-east, receiving south of Monivea a west-to-east tributary, the Knockbrack chain. On the west of Menlough a more or less parallel chain runs from Ryehill past Carbally Castle.

In addition to the foregoing, several isolated groups of eskers are to be seen in this district, as for instance those of Cloghmoyle Castle and of Pollsillagh.

10. *The Gortachalla chain.*—About 11 miles north-west of Galway town, on the west of Lough Corrib, a chain of eskers, about  $4\frac{1}{2}$  miles in length, runs almost due east, passing north of Gortachalla Lough. There is a bare possibility that this may belong to the Ballyhaunis system.

### *The System of the Midlands.*

This great and complicated system may be divided into four subordinate systems; these are:—

- |                     |                           |
|---------------------|---------------------------|
| I. System of Clara. | III. System of Edenderry. |
| II. „ Parsonstown.  | IV. „ Trim.               |

I. THE SYSTEM OF CLARA.—This consists of several subsidiary and three main chains, which run from west to east, converging eastwards, to unite near Judgeville, about 10 miles east of Clara. They are shown in detail on sheets 97, 98, 99, 107, 108, 109 of the one-inch map of the Geological Survey, and are described in the corresponding Memoirs by Messrs. J. O'Kelly, F. J. Foot, G. H. Kinahan, and R. G. Symes.

Beginning on the north, and proceeding southwards, these chains are as follows:—

- i. Chain of Newtown-Loe (5 miles south-west of Lough Ennell).
- ii. „ Seven Churches (Clonmacnois).
- iii. „ Ballyduff (passing about  $1\frac{1}{2}$  miles north of Tullamore).

i. *The Newtown-Loe chain.*—This includes the following chains:—

1. Newtown-Loe chain proper and the tributary chain of Ballynagore (about 5 miles south-west of Lough Ennell).
2. Streamstown chain (the southern part of which is nearly 6 miles west of Lough Ennell).
3. Ballymore chain (about 9 miles west of Lough Ennell), and the parallel chain of Ballymahon (about 12 miles west of Lough Ennell).
4. Athlone chain, with several tributaries, including that of Lough Funshinagh.

1. *The Newtown-Loe chain proper.*—This commences in the bog of Donore Bridge, with a direction from north-west to south-east; but, after a straight course of about a mile and a half, it turns at first east, and then south-east, forming a wide convex curve open to the south, and then enters the main system of Clara.

About the middle of the curve the small chain of Ballinagore, coming from the north, is brought into close proximity with it; and with this the eskers west of Lough Owel and Lough Ennell should probably be associated. Where its course is most eastward a single long esker runs parallel at no great distance from it, the intervening ground being occupied by bog.

The height of the chain is given as about 70 feet, the angle of the slope on each side as  $30^{\circ}$ . Large blocks of limestone rest upon its flanks.

2. *The Streamstown chain.*—This complicated chain, nearly 12 miles long altogether, running, on the whole, north and south, may represent a northern feeder of the Newtown-Loe chain. About Streamstown it forms a *plexus*, of which fig. 3, taken from the Survey Memoir, gives a good representation.

3. *The Ballymore chain.*—This broken chain extends southwards, roughly parallel to the southern part of the Streamstown chain, and about  $3\frac{1}{2}$  miles to the west of it. About 6 miles south of Ballymore it turns sharply south-eastwards;  $1\frac{1}{2}$  miles further on in that direction we come to an isolated esker with the same direction, and therefore parallel to that portion of the Newtown-Loe chain already mentioned as running north-west to south-east, the distance between them being 2 miles. This may possibly represent the southerly termination of the Ballymahon chain.

The N.N.W. to S.S.E. chain, lying about 2 miles west of that of Ballymore, is the Ballymahon chain.

4. *The Athlone chain.*—This is a very fragmentary and complicated chain. Starting from the west among the confused group of eskers east of Killeglan (fig. 4), it runs in a very irregular way, with a generally easterly trend; north

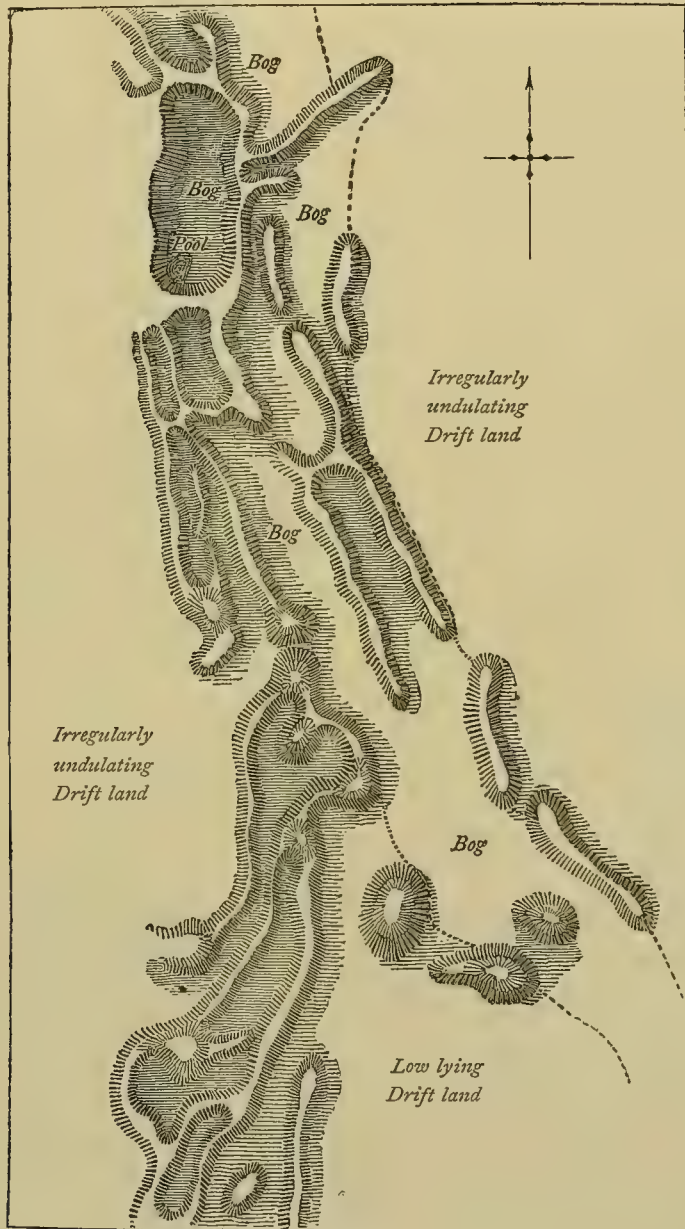


FIG. 3.

of Moate (fig. 4), however, it takes an E.S.E. direction, and finally trends again to the east; thus repeating the behaviour of the two preceding chains. Several tributary chains from the north enter or approach it near its western extremity, one of the largest of these being that which commences near Lough Funshinagh.

A railway-cutting, east of the town of Moydrum, affords a good section through one of the eskers of this chain; beds of gravel and sand with seams of hard clay are exposed; oblique lamination is common, and the beds are curved, contorted, and faulted.

ii. *The Seven Churches chain* (Clonmacnois).—This chain (fig. 4), which is over 43 miles long, maintains throughout its course a general west-to-east trend. It is fairly continuous, though one large gap, nearly 4 miles long, breaks through it  $2\frac{1}{2}$  miles west of Clara. It runs transversely across the valley of the Shannon, and thus lies on lower ground in the middle part of its course than at either end. The main chain may be subdivided as follows:—

1. Ballinasloe chain, with the Cloonigny tributary.

2. Seven Churches chain, with the Clonmacnois loop.

On the west of the system a confused cluster of eskers, which cannot be reduced to order, occur over a considerable tract of country, about the watershed of the tributaries to the Suck and the Dooyertha river. A definite chain first appears about  $6\frac{1}{2}$  miles west of Ballinasloe. This is the commencement of—

1. *The Ballinasloe chain*.—This, after running east to Ballinasloe (fig. 4), curves gently to the south-east, crosses the valley of the Suck, passes near Oldtown, and then, curving slightly northward, ends in the callows of the Shannon without coming into direct connection with the Seven Churches chain.

A tributary chain, that of Cloonigny, rises some  $5\frac{1}{2}$  miles west by north of Ballinasloe, near the village of Cloonigny; a continuation of this on the west and north may be found in the eskers of Doon and Annagh.

2. *The Seven Churches chain*.—North and south of the village of Aughrim, about 5 miles W.S.W. of Ballinasloe (fig. 4), several eskers converge towards a west-to-east chain, which runs almost parallel to that of Ballinasloe.

This is the Seven Churches chain; it runs for a great distance almost due east, crosses the Suck, traverses the great bogs which lie between this river and the Shannon, affording almost the only dry land of this district, crosses the Shannon, and soon afterwards turns somewhat sharply north-eastwards to Seven Churches. From Seven Churches it again runs eastwards, and for some distance the chain becomes double, consisting of two parallel members—a northern, over which runs “The Pilgrim’s Road,” and a southern, which may be called the Clonmacnois loop.

It is a remarkable fact, first pointed out by Mr. F. J. Foot, that the breach in the Seven Churches chain, through which the river Shannon flows, is only just large enough for the passage of this river; attention is called by Mr. J. O’Kelly to a similar feature in the Newtown-Loe chain, where the river Brosna passes through it, and again in the Ballyduff chain, where this is traversed by the Silver river.

Fig. 4.



iii. *The Ballyduff chain.*—This is a continuous esker, 11 miles in length, with a very regular and steep slope on the northern and a very gentle one on the southern face.

II. THE SYSTEM OF PARSONSTOWN.—This consists of the following chains :—

1. Killimor chain.
2. Tynagh chain, and
3. Duniry chain, converging into
4. Fairfield chain.
5. Frankford chain.
6. Banagher chain. (All in fig. 4.)

On the west the system commences in three tributary chains, viz. those of Killimor, Tynagh, and Duniry (fig. 4), which rise immediately east of the high ground formed by the northern termination of the Slieve Aughta mountains.

1. *The Killimor chain.*—This, about 7 miles long, commences near Dartfield, and runs eastward to its termination in the callows of the Shannon.

2. *The Tynagh chain.*—This begins in a series of isolated hillocks, not far from Masonbrook House, and runs past the village of Tynagh, to join the Duniry chain, some little distance west of Fairfield.

3. *The Duniry chain.*—This begins in separate hillocks about the source of the Duniry river ; it receives the Tynagh chain, and is continued eastward as—

4. *The Fairfield chain.*—This approaches closely to the chain of Killimor, but without actually reaching it, and ends just on the borders of the alluvial flats of the Shannon.

The preceding chains, which may be collectively designated the sub-system of Portumna, are represented on sheet 116 of the one-inch map of the Geological Survey, and are described in the accompanying Memoir by Mr. G. H. Kinahan. They present us with one of the most beautiful examples of river-like distribution to be found among the eskers of Ireland. Mr. Kinahan states that numerous large blocks of limestone are perched on some of the eskers of this group ; the largest block recorded measured 12 feet by 9 feet by 4 feet. It lies on the slope of the Killimor chain, near the town of Killimor.

5. *The Frankford chain.*—This (fig. 4), which appears to be the natural continuation of the Portumna sub-system just described, is, however, separated from it by the Shannon with its bordering callows. It is fairly continuous, with a length of about 25 miles. N.N.E. of Parsonstown it is narrow and strongly marked, the summit of the ridge being only wide enough, in some places, to admit of a roadway ; its slopes have an angle of from 30 to 35 degrees, and its

height varies from 35 to 50 feet. It terminates between two and three miles south-west of Tullamore.

I had the advantage of studying this esker under the guidance of Lord Rosse, who pointed out to me numerous boulders and pebbles of Galway granite amongst the rubbly material of which it consists in great part. Lord Rosse also showed me specimens of Connemara marble which he had collected from the esker.

South of Parsonstown are several eskers, trending from west to east, which, with that near Muddy Lough, more to the east, may be doubtfully associated with the Frankford chain.

6. *The Banagher chain.*—This not very well-marked esker (fig. 4), which occurs a few miles north of the Frankford chain, begins a little more than two miles to the east of Eyrecourt, and runs due east, ending against the Shannon.

III. THE SYSTEM OF EDENDERRY.—The only important chain of this group is that of Philipstown; it lies south of Edenderry, and begins east of Philipstown as a low ridge, 13 feet in height, but rises eastward until it attains a height of 59 feet, and is then 286 feet above the sea-level; it sinks further on to a height of 25 or 30 feet, and after a course of  $3\frac{1}{2}$  miles in all, disappears in a bog. It recommences further to the east, forming a ridge  $3\frac{1}{2}$  miles long, with a height of from 20 to 50 feet. The country to the east of this chain consists chiefly of limestone gravel.

A small esker, known as Carrick Hill, occurs to the north of Edenderry. Still further north are two small chains, one near Thomastown, and the other near Ballinadrumny, the small town of Kinnegad lying between them.

IV. THE SYSTEM OF TRIM.—Near Trim, and to the east of it, a single chain of eskers commences, and runs from N.N.W. to S.S.E. for about six miles. Near its commencement its summit is 233 feet above sea-level, but the gravel mound, in which it ends, attains a height of 402 feet above sea-level.

Extending from the town of Athboy, up the valley of the Athboy river, a tributary to the Boyne, is a compound chain of eskers, which may be provisionally associated with the Trim system.

Several isolated chains occur in the Midlands, of which the relations cannot at present be determined; that at Clonaslee, and another at Geashill, may be cited as examples.

The chain of Mountmellick and Maryborough would appear to belong to the valley of the Barrow.

*The Portumna Kame-Belt.*—Though we have already crossed the ground of this belt (fig. 4.) in following the courses of the Killimor, Tynagh, and Duniry eskers, we have reserved the mention of it for this place, on account of its apparent individuality and exceptional character. This very remarkable feature of the Midland system is the occurrence of a great number of short esker and

gravel hillocks over a narrow tract of country, not more than one to two miles broad, which extends due north from Portumna for a distance of about 11 or 12 miles. The eskers, though short, are long enough to give evidence of a general northerly trend, and about Kiltormer, where several eskers of the more usual elongated form are associated with them, the northerly direction is maintained. Many of the eskers over this zone are distinguished by their curious forms, resembling the letters U, V, L, and Y. It will be convenient to distinguish this zone of thickly scattered mounds as the Portumna Kame-belt. Near the middle of its course a spur proceeds from it and extends eastwards towards Eyrecourt. Most of the eskers of this process trend north and south; but the end one, nearest to Eyrecourt, runs due east and west. The process may be termed the parallel series of Eyrecourt.

Having returned to this neighbourhood, we may take this opportunity of mentioning that sporadic occurrences of short eskers are common to the west of the Portumna belt; and about the head waters of the Ardultagh river they are richly strewn over a circular area of about three miles in diameter. It has already been shown that the Ballinasloe chain commences within this area; and it may now be added that another chain, the Dunsandle esker of Mr. G. H. Kinahan (about four miles north-west of Loughrea), arises here; this, however, takes a south-westerly course, following the waters of the small stream there. It passes the village of Dunsandle, and terminates near Riverville Castle. North of it another chain follows the valley of the Dooyertha river, near Rathgorgin. South-west of these are numerous scattered eskers, or broken esker chains, as those of Castleboy and Killrust, of Aggard and Monksfield, and a single ridge more to the west, which is remarkable for its association with Lough Fingall. Both lough and esker have approximately the same shape and dimensions, and run close together from north to south side by side. This is rendered the more interesting by the fact that both lake and esker rest on the bare rock of a driftless area.

*The Caltra Chiasma.*—Although this is within the area of fig. 2, where we have been already, we consider it here apart to emphasise its remarkable character. It is a singular arrangement of eskers to be seen north of Slievanulty, between the rivers Bunowen and Shiven, over the south-west corner of sheet 97 of the Geological Survey map. The eskers themselves are usually straight and simple; some are long in comparison with their breadth; others short, narrow ellipses; the most striking feature, however, is their arrangement in two groups of parallel members, the ridges of one group running from south-east to north-west, and of the other from south-west to north-east. The larger part of the north-eastwardly-directed group lies on the west of the district, and of the north-westwardly-directed group on the east thereof. The two groups, however, are not quite separate, but implicated with each other, so that some of the north-

eastwardly-directed ridges occur on the eastern margin of the north-westwardly-directed group, lying between some of the north-westwardly-directed ridges; and, similarly, some of the north-westwardly-directed ridges lie within the area occupied by the north-eastwardly-directed ones. For this reason it will be convenient to speak of the two groups as the Caltra chiasma, Caltra being a village lying within the system. Although most of the eskers of the chiasma are straight, there are a few exceptions; two, in particular, may be mentioned; they will be seen in the middle of the north-westwardly-directed group, and are of especial interest, since they only just fall short of uniting the different directions of the two groups in themselves. One commences as a north-westwardly-directed ridge, and curves round until it points east of north; its neighbour on the west overlaps it for the first half of its course, and continues to approach the north-east direction of the second group, without, however, quite succeeding in attaining actual parallelism. So that here the two groups may be said to inosculate.

This completes our survey of the two great systems of Irish eskers. Several isolated chains and ridges occur outside these systems, such as those of Roscrea, and those to the east of Lough Derg, to which we should add, on account of their interest as occurring in or near Dublin, that on which Christchurch stands, and the small chain of Greenhills and Lucan. Others, but they are not numerous, are to be found in parts of Ireland which lie outside the boundaries of our map.

### Summary and Conclusions.

Our knowledge of eskers is, in many important respects, singularly incomplete; and there are many problems connected with their origin which might perhaps be readily solved by an appeal to the eskers themselves. Deeply conscious of my own ignorance respecting several particulars which yet may be accessible to observation, I had originally intended to publish the accompanying map without comment; but having been led to add descriptive matter, and then an account of the literature of the subject, I venture to complete this essay with a short summary of facts and general conclusions.

A map of an esker system (Pl. LXIX.) presents a remarkable resemblance to a map of a river system. The narrow linear outlines, the meandering course, the branches converging like tributaries, or diverging like the channels of a delta, the loops and knots are singularly alike in each.

The chief difference which distinguishes the esker chain from a river system is its discontinuity, gaps of various length, from a few yards to several miles, breaking it up into a number of links of unequal size.

The explanation of this feature has been much discussed; chiefly, it may be imagined, because it is susceptible of explanation in so many different ways on

the hypothesis of a melting ice-sheet. It might readily result from subsequent denudation. Surprise has sometimes been expressed that the eskers should have survived the turbulent movement of the streams discharged from the disappearing ice. Perhaps in these great gaps we have a measure of the breaching efficacy of the liberated floods. Equally possible, however, is the suggestion that the gaps are original, marking stretches of the glacial rivers where sediment was never deposited as might readily happen for reasons so many and obvious that it were waste of time to consider them.

The eskers of Ireland are usually confined to comparatively low ground; they are consequently mostly distributed over drift-covered country. The ground on which they stand seldom rises more than 350 feet above the sea-level, though some large isolated mounds are found at a height of 400 feet. Their height above the surrounding country is rarely over 70 feet, not often over 60 feet.

Their side slopes are subject to great variation, but are often steep, sometimes making an angle of  $35^{\circ}$  with the horizon; both sides may be almost equally inclined, but more commonly one side has a steep, and the other a gentle slope.

When both sides are fairly steep, it is probable that the esker was deposited in a narrow channel and was supported by the ice on both sides. When one side is gently sloping it is possible that the channel was wide, and that the esker rested against the ice only on one side.

The run of an esker system, as we may term the direction towards which its several chains and branches converge, may be with the slope of the ground, or against it. The system of Ballyhaunis is an example of the former case; the sub-system of Portumna of the latter. A system which runs with the slope of the ground in one part of its course may, however, run against it in another; as, for instance, the system of the Midlands, which runs with the ground on its western side, as in the case of the Portumna sub-system just cited, and against it on its eastern side, thus descending to the Shannon in the one case, and rising from it in the other. The explanation of this may fairly be postponed until we have taken into account the direction of the movement of the ice.

The structure of the Irish eskers, like that of those known in other parts of the world, differs greatly in different eskers, and even in different parts of the same esker. In some places, as pointed out in the earliest Memoirs of the Geological Survey, it is confused, consisting of a rubble of blocks of stone only slightly waterworn, but without glacial scratches, piled together in disorder; in other places it is beautifully stratified, coarse and fine gravel, sand, and occasionally clay, alternating in rapid succession. False bedding is common, and in many cases a rude tendency to so-called anticlinal structure is seen, *i.e.* the beds of stratified material conform more or less closely to the slopes of the esker. I should prefer

to call this over-cast bedding, since it appears to be due to the casting down of sediment over a steep slope; the material sometimes lies at a high angle.

At the base of some eskers horizontally bedded sands and gravels are often met with, and, in one instance, as pointed out to me by Mr. Praeger, in the Greenhills esker, near Dublin, this was seen to be beautifully ripple-marked.

What are evidently disturbances of the bedding, produced subsequently to its formation, are far from uncommon. In the Greenhills esker, close to Timon Castle, Dublin, a particular bed of pebbles can be traced along a horizontal course for a considerable distance; but at one place this is interrupted for an interval of about 20 feet; fragments of it, however, are clearly visible lying along an irregular curve beneath a mass of disorderly sand and gravel. Cavings in, such as this, suggest that blocks of ice become buried up within the esker, and by their subsequent melting the overlying material was deprived of support.

Faults are not uncommon, contortions are frequently, and reversed faults occasionally, met with. Mr. Close informs me that a good instance of a reversed fault was pointed out to him by Mr. F. J. Foot in a cutting through an esker on the right-hand side of the road going from Boyle, to Moygara, about four and a-half miles due west of Boyle, which is in county Roscommon. The settling of one side of the ice on one side of the esker might produce a thrust sufficiently powerful to produce a fault of this kind; it does not necessarily imply that the whole glacier was still in a state of flow.

The large blocks of stone resting on the surface of an esker, and sometimes included within it, to which the officers of the Geological Survey so frequently call attention, are readily explicable as morainic fragments left behind in the last stages of the retreat of the ice. In common with many other phenomena they suggest that the eskers on which they occur were deposited rather in tunnels than in open valleys of the ice.

Not at all infrequently a core of coarse and confusedly arranged material is found within a mantle of exquisitely stratified sand and gravel, which may be repeatedly faulted.

From all that I have seen of the structure of eskers, I should certainly conclude that in most cases they have been deposited on the place where they are now found by the action of running water, and that they have not been precipitated in mass from the bottom of sinking ice-cansons.

A great number of observations on the direction of glacial striæ over many parts of Ireland have been recorded by the officers of the Geological Survey; but the most important systematic study of these and other indications of the movements of the glaciers of the Pleistocene Period, we owe to the Rev. Maxwell Close, whose Paper on the subject we have referred to above, p. 787. Mr. Close describes (i.) a system of rock scorings, which show the direction taken by the ice at the

time it was abrading the bare rocks of the country, and (ii.) a system of drumlins, which indicate its direction, after or during the deposition of the boulder clay. But these two systems, that of the striæ and that of the drumlins, correspond, giving concordant indications, and thus prove that the movement of the ice was that of a steady and persistent flow, throughout a great part of the Glacial Period.

Mr. Close has laid down these two systems on a map (given also in the *Geol. Mag.* for May, 1867), showing the general glaciation of Ireland, on which he also represents a third system of indications, those furnished by the transport of rocky material, and the evidence of this is in strict agreement with that of the two preceding systems. We have transferred to our maps of eskers some of Mr. Close's results, indicating a line of flow by a straight line, or, when its direction is known, by an arrow; the nature of the evidence is shown by a ( $\Delta$ ) for drumlin, a ( $\Sigma$ ) for rock striæ, and a (T) for transport of material, placed by the side of the line or arrow.

It follows from Mr. Close's observations that, during the period with which his map is concerned, the area of Ireland was glaciated by ice formed upon its own surface, except the eastern side of Ulster, which was swept by an ice-flow from a little west of north to a little east of south, which flow doubtless came from the western side of Scotland. A great flow proceeded to move southward from the north-east neighbourhood of Carrick-on-Shannon; but evidently, in consequence of the resistance of the ice to the southward, it divided near where that town now stands, part going south-eastwards towards Dublin, and part turning sharply westward from the plain country and then north-westward, when it was joined by the northward flow from the head of Lough Corrib, to move off the present area of Ireland in the neighbourhood of Killala bay. The south-eastern part of Ireland has been glaciated by ice, first flowing eastwards, then south-eastwards, and then southwards; the county Clare and its neighbourhood was swept by ice moving south-westwards, the place of parting of these two great flows being about 18 miles inland of the head of Galway bay. The hill-country centres of ice-dispersion were all on the west of Ireland; there were none elsewhere; though there were many corry-glaciers on the east and south-east of Ireland.

The movement of the ice in the districts occupied by the esker systems is less completely known than in the regions surrounding them. Irish geologists are credited with a discovery they have not made, and are not likely to make, of a coincidence between the direction of eskers and ice-flow (Woodworth, *loc. cit.*, p. 205). Mr. Woodworth does not cite authorities; but the asserted coincidence, when it exists, is only accidental.

In this connection it may be pointed out that, in addition to striations, drumlins, and transport of material, we have a fourth criterion supplementing these, by

which the direction of ice-flow may be inferred. This is given by the bogs. It will be found that, in a district where the direction of the ice-movement has already been discovered from observations on drumlins and striæ, the smaller bogs present individually an elongated form running in the same direction as the ice-flow, or they form a network, the meshes of which are all mostly elongated in the same direction. The bogs were originally lakes in the boulder clay, and when these occur in the form of isolated elongated troughs, they may be regarded as the reverse of drumlins; when, on the other hand, they form a network of waterways, this may be owing to the existence of numerous drumlins rising above the level of the water. In either case, whether indicating an elongated trough or the presence of drumlins, the form of the bog becomes a valuable aid in the discovery of the direction of ice-movement by mere inspection of an ordinary geological map. On reference to Plate LXIX., it will be seen that in the case of the Ballyhaunis system all the evidence concurs in testifying to a movement of the ice from the south-east to the north-west, while the esker chains, for the greater part of their course, run manifestly at right angles to this, or from south-west to north-east. This would suggest that in their case the water channels in the ice were determined partly by crevasses. We have already seen that these eskers run against the slope of the ground, and it may be that the apparent convergence of the chain northwards, as described above, is to be interpreted as a divergence southwards, and that the water drained from the Ballyhaunis ice towards Lough Corrib and Galway Bay.

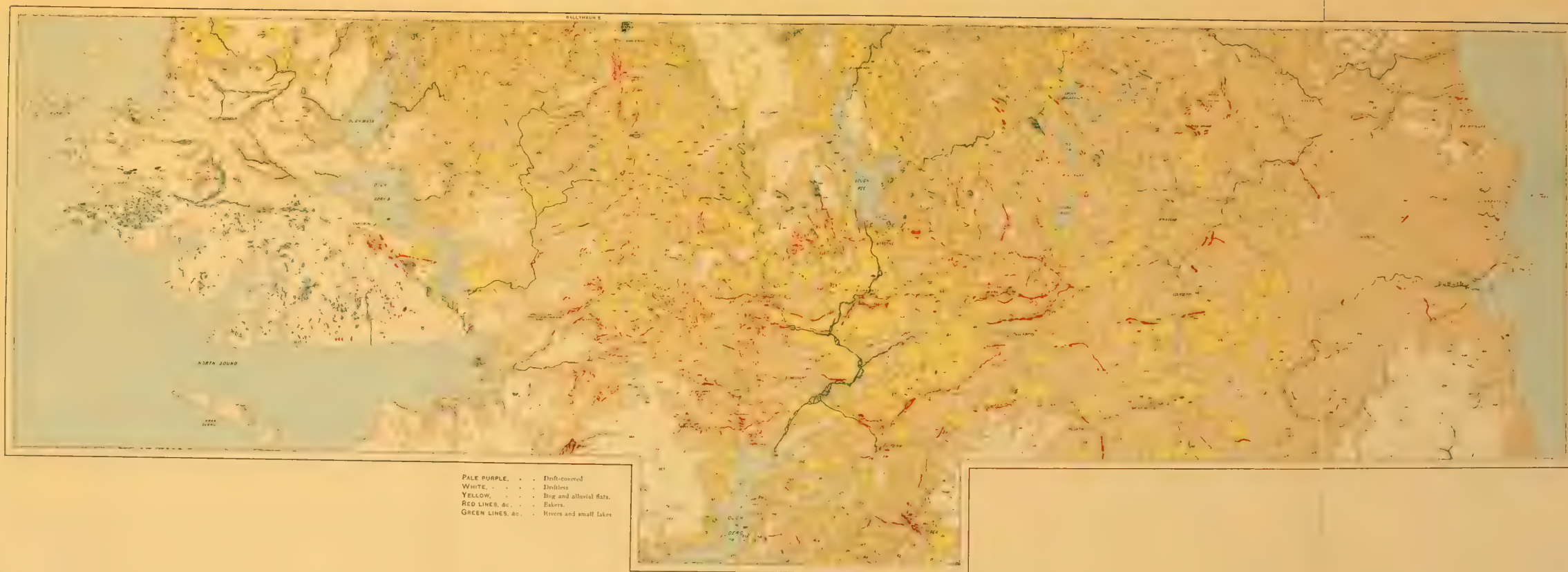
If now we turn to the Midland system we shall find that associated with a general absence of indications of the direction of ice-flow is a general absence of elongation in the form of the wide areas occupied by bog. From this it would appear that the movement of the ice in the centre of the country was sluggish; it probably accumulated here in an immense pool, and, possibly persisted as a *piedmont* glacier up to the closing stages of the Glacial Period. In the case of the Portumna sub-system the flow of the ice, as shown by drumlins, bogs, striæ, and transport of material, was in the same direction as the run of the eskers, *i.e.* on the whole from west to east. That the subglacial streams flowed for a considerable distance in this direction is suggested by the occurrence already mentioned of Connemara marble and Galway granite in the esker of Parsonstown. The Portumna belt runs transversely to this east-and-west movement, and like the eskers of Ballyhaunis may have been determined by crevasses.

## EXPLANATION OF THE MAPS.

The large map, Plate LXIX., is on a slightly smaller scale than one inch to eight miles, say one inch to 8.24 miles. The very pale brown indicates drift-covered ground, the white driftless ground, the yellow bogs and alluvial flats. The green lines and spots mark rivers and small lakes. The red lines and spots represent the eskers. The short, thin, straight lines, generally with arrow heads, show the direction of the ice-movement. (See also p. 820, *supra*.) The numbers scattered over the map give the elevation of the ground above the sea-level, in feet.

Figs. 2 and 4 exhibit portions of Plate LXIX. on a larger scale, viz. one inch to very nearly five miles. The white now means drift-covered ground, the horizontal ruling driftless ground, and the diagonal ruling bog, or alluvial flats. The thick lines (easily distinguishable from the lines indicating rivers) and the spots represent the eskers. The straight lines, generally with arrow heads, show, as before, the direction of the ice-movement.

END OF VOLUME V.



MAP OF ESKERS.





## TRANSACTIONS (SERIES II.).

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VOL. I.—Parts 1-25.—November, 1877, to September, 1883.

VOL. II.—Parts 1-2.—August, 1879, to April, 1882.

VOL. III.—Parts 1-14.—September, 1883, to November, 1887.

VOL. IV.—Parts 1-14.—April, 1888, to November, 1892.

VOL. V.—Parts 1-13.—May, 1893, to July, 1896.

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### PART

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